A Mars Landing by the 4th of July?

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Flying Wing

How Test Pilot Glen Edwards Met His Fate in the YB–49

The Lawsuit That Shook Flight at Its Foundations— *Wright v. Curtiss*

Is Every Airplane Beautiful? (Get Real.) p.56

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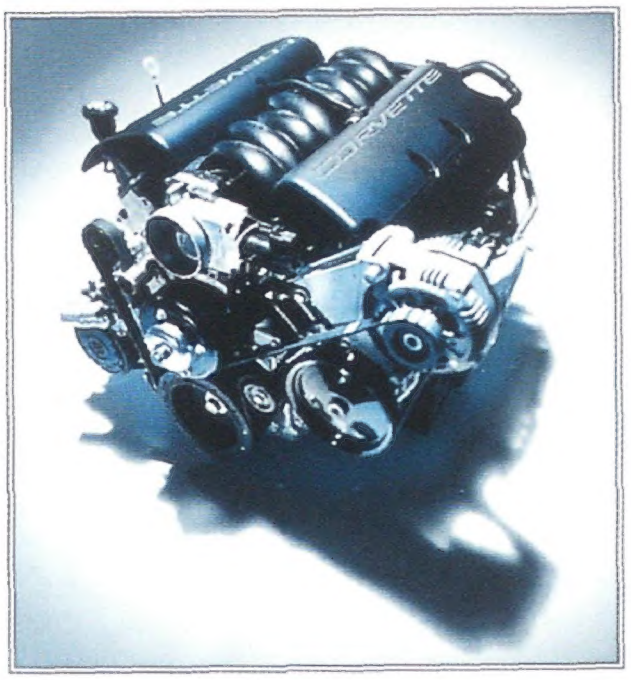
{The honest-to-goodness tru

Announcing the I

By David Hill, Ch

Of all the speculation about the new Corvette over the years, the biggest misconception was that it would be a sort of warmed-over C4.

This was because of the way we masked all of our prototypes to make them look like C4s. We certainly didn't try to dispel this notion.



{ The engine is entirely new: aluminum, deep-skirt, 5.7L, 345 hp at 5600 rpm, 350 ft.-lbs. of torque at 4400 rpm. }

In fact, we were so tight-lipped about the C5 all along that I think people just assumed we had nothing to say about the car.

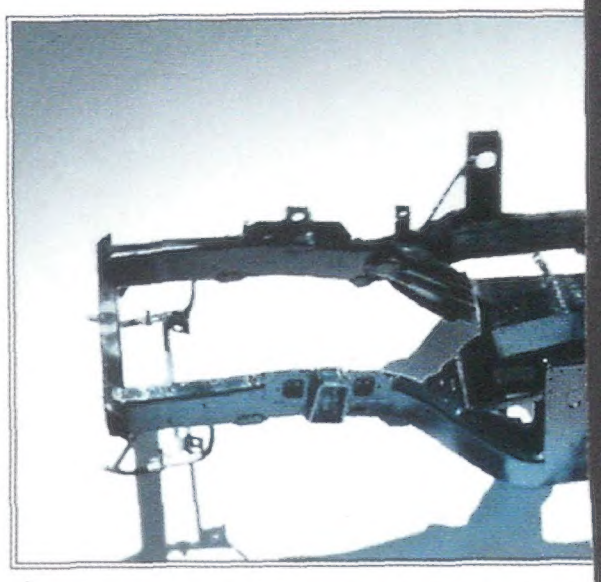
When the reporters finally drove it, they were probably a little awestruck that the Corvette had been reinvented. And, in fact, there are only a few holdover parts on the car; everything else is new. But that was the intention all along, to make the new Corvette a big surprise, a revolution.

To Change A Classic The big dilemma right from the outset was how much change to incorporate into this new car. The goal was to maintain the spirit and soul of past Corvettes. We examined the weak points and turned them into strengths. I like to say the things that were good, we made great, and things that were great are even better.

In fact, there was even some concern about making the car too civilized, and maybe people would lose their fascination with the Corvette. When this was researched, we were all surprised to find that far more important than how this car looked — three times more important — was how good it was, how dependable and reliable. This became our top priority.

Ride, Handling, Structure The performance numbers are impressive [175 miles-per-hour, 0-60 in 4.7 seconds (manual), 345 horsepower; speculation about all these numbers has been true], but it's the ride and handling that really make the C5 a different car.

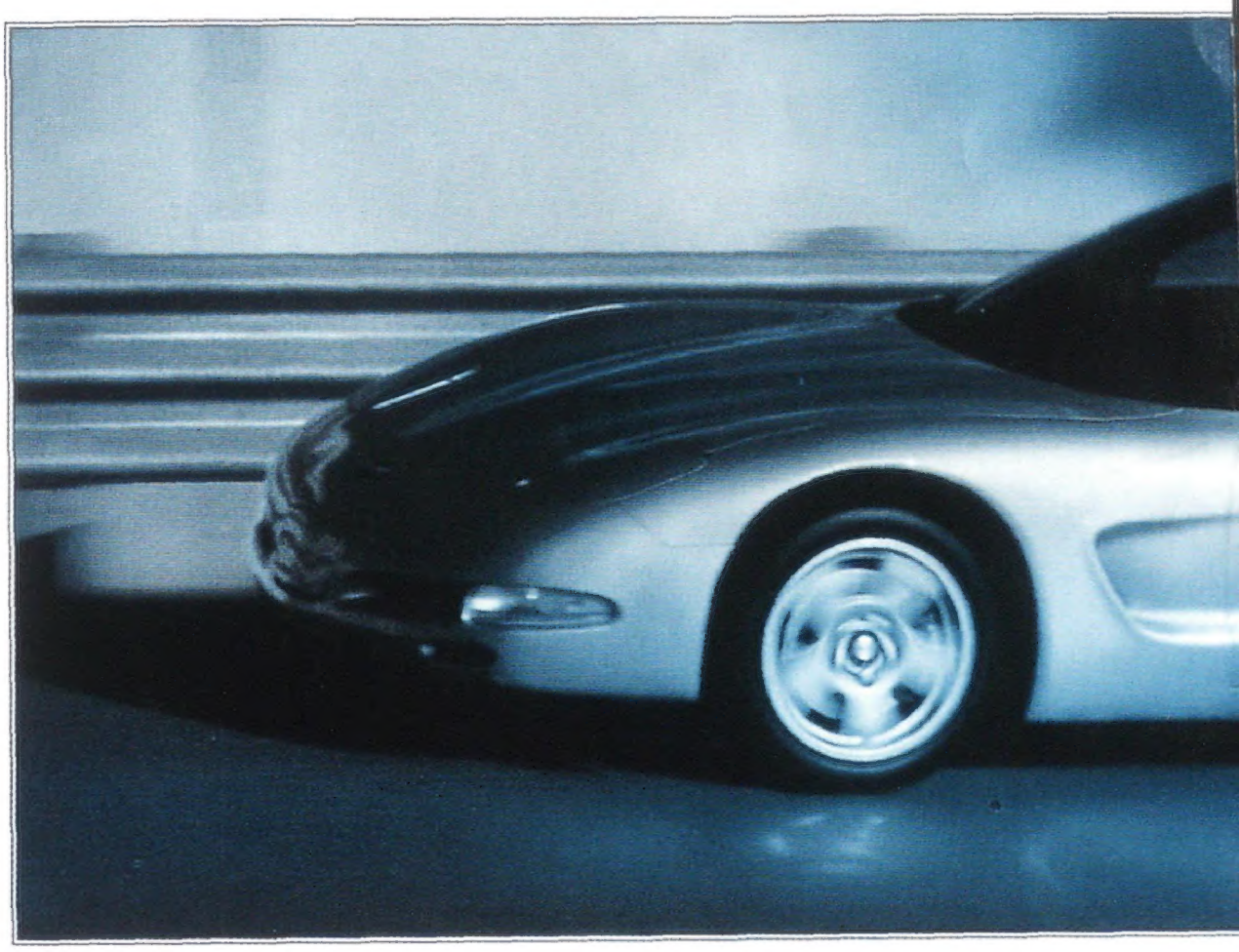
The handling is easy, natural, free of surprises; you wouldn't have any hesitation about sending a friend out to drive this Corvette. Even the most



{ The new center tunnel structure and hydroformed perim

complete novice will feel the difference in ride quality. You can go 500 miles or more in one sitting and still be in really good, alert shape, with a clear head and clear hearing, because the ride has been quiet and easy.

We had some people drive the car from Ohi down to Florida and Arizona. They talked abo how good they felt because the car is very kin



T h e N e x t

bout the C5 Corvette, after all.}

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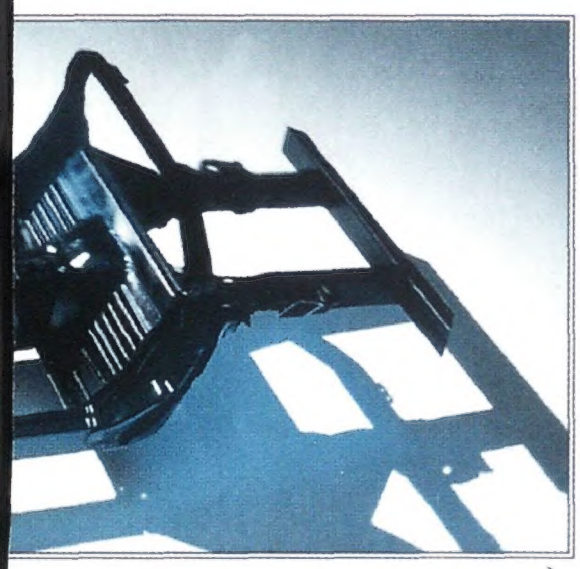


e make the new Corvette 450 percent stiffer than the C4.}

More than anything else, the improved ride the result of increased rigidity. Structurally, e C5 is 450 percent stiffer than its predecessor, d it shows. This stiffer structure allows the w SLA (short-arm, long-arm) suspension to its job properly.

No other car has achieved the feeling of a very pensive touring sedan, even though it's a high-performance sports car, and even though the roof is removed. In fact, the C5 has the stiffest frame of any open-roof production sports car. It's solid; it communicates an unprecedented level of goodness because of its breakthrough, best-of-class kind of structural integrity.

Entry, Egress, Leg Room Now the interior space is expanded due to the extended wheelbase and the new rear-mounted transmission and fuel system layout. There's more leg room, and we made entry and egress easier.

No matter how much someone says that a sports car should be challenging, we found that while people will put up with minor inconveniences, they'd much rather not be hassled by a car. Even sports car drivers want leg room, and they like to get in and out of their car easily. Almost everyone we asked felt the same way, from average-size people to professional football players who attended a seminar we held in Chicago.

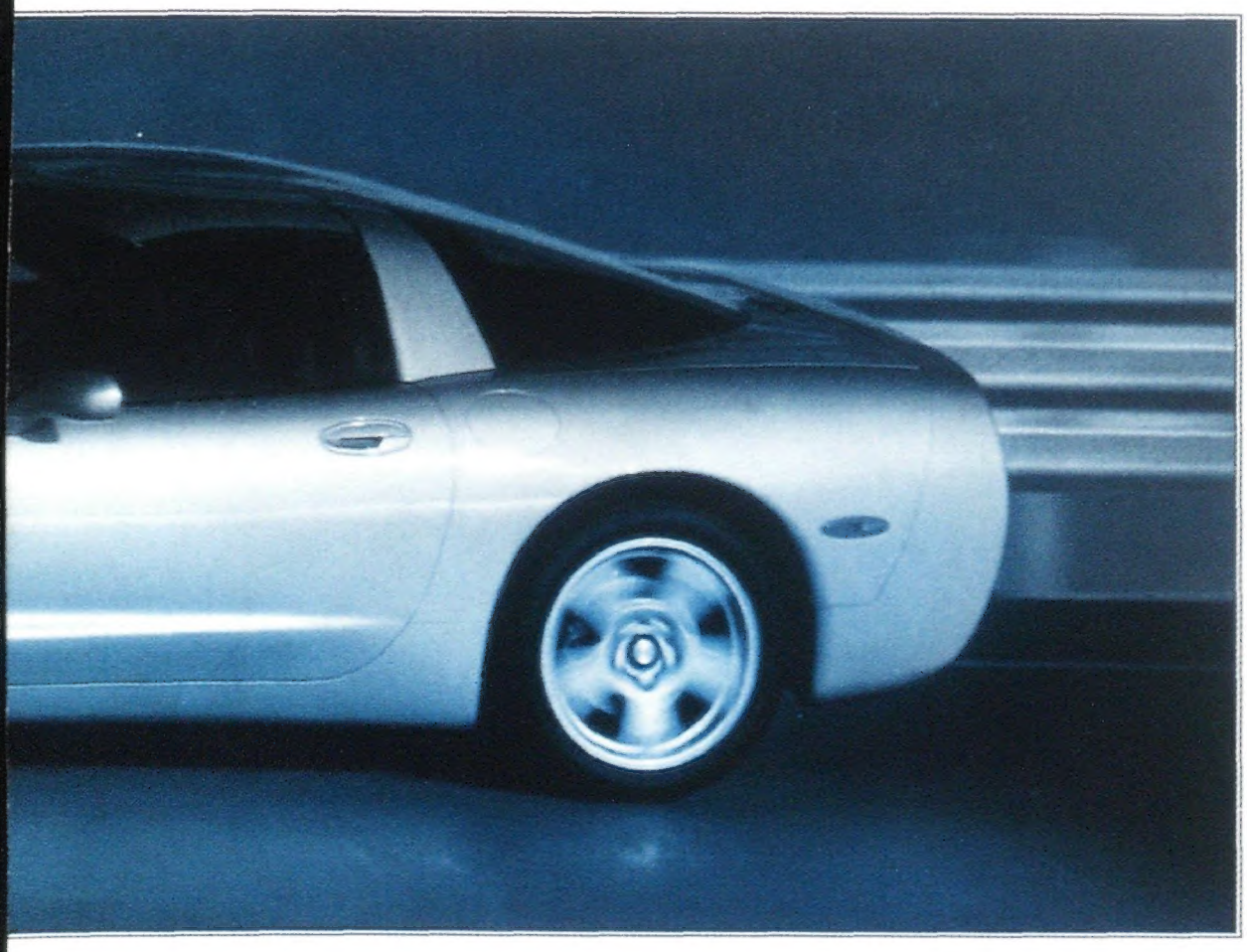
{ The C5 transmission is located in the rear for better weight distribution and increased interior space. }

The Next Corvette While the C5 is in some senses a traditional small-block V8 Corvette, it really is a different car than the Vette you've known. It's different in ways I think people will appreciate.

It's been a long, challenging project, and it's been hard to keep quiet about this whole thing all this time. Now the new Corvette is real. And now all those years of speculation end right here: with our new car, right on the showroom floor.

As for the speculators and spy photographers, I guess their work is done.

Then again, there's always '98.



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Volume 12, Number 2

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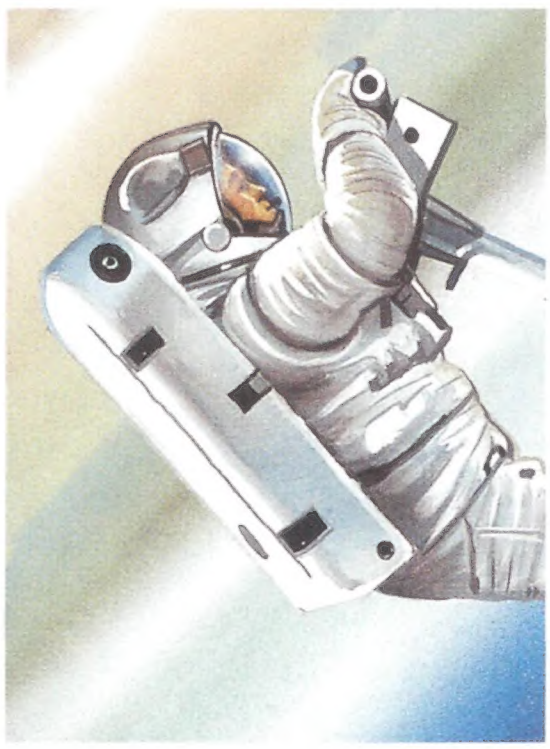

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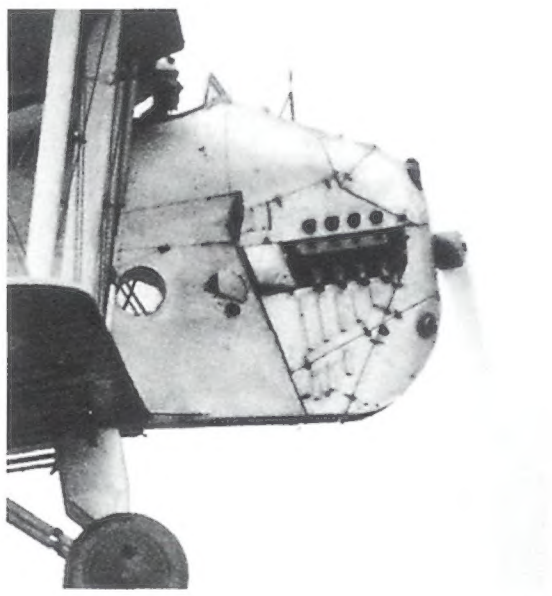

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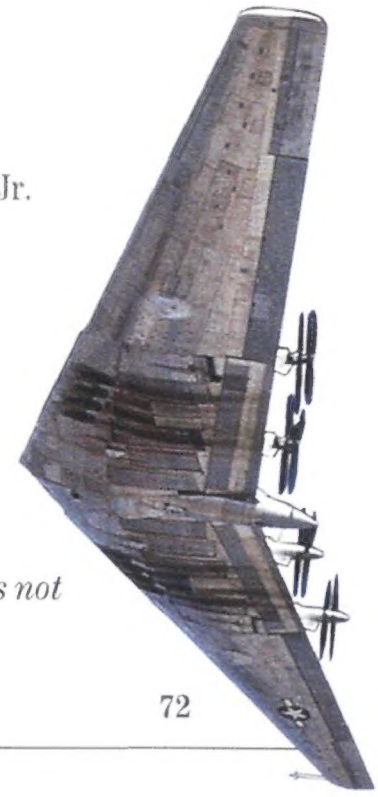

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Cover:
Northrop's Roy Wolford photographed the extraordinary YB-49 Flying Wing over Muroc Dry Lake in 1948.

Departments

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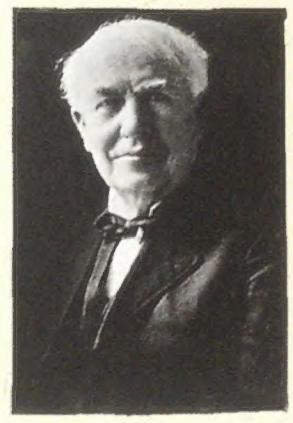

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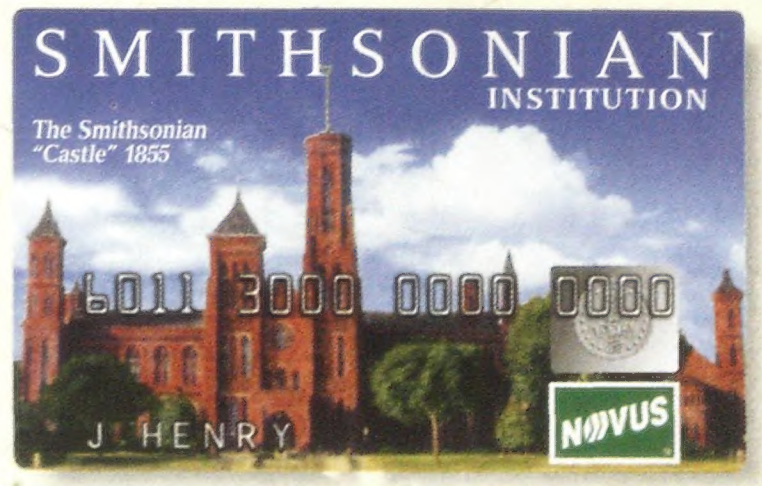

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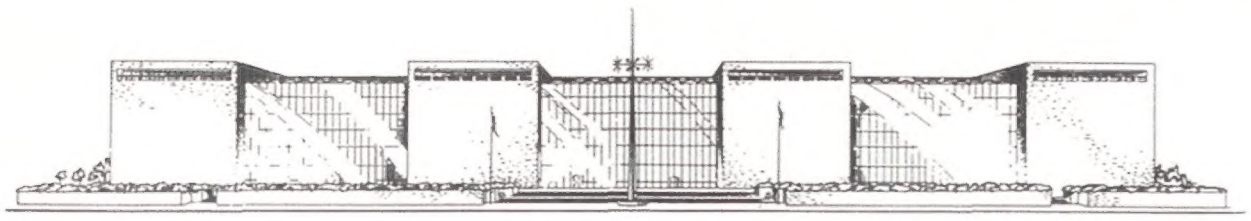

Welcome, Friends

Sitting in the head chair of the world's most visited museum provides a great deal of satisfaction. Just as Michael Collins, Walter Boyne, Martin Harwit, and several interim directors found before me, the job can be most interesting. The National Air and Space Museum is open 364 days each year (we're closed only on Christmas), and the number of visitors varies between 10,000 and 50,000 a day, depending on the day of the week and the time of year, so the place is always humming.

Sometimes one of those many visitors turns out to be an old friend who has decided to visit the Museum and who calls me up from the information desk near the Independence Avenue entrance. Like so many others, they have come to think of the National Air and Space Museum as a wonderful place to share a love of aviation and space.

And that brings me to a subject close to my heart: the great aerospace fraternity to which we all belong.

I have long maintained that English may be the official language of aviation in the world, but when you speak "aviation" you can go anywhere and talk to other pilots regardless of what other languages they speak. There is a camaraderie borne of early risings, missed meals, long hours, late nights, low fuel, beautiful cumulonimbus, clear blue skies, rain, sleet, snow, lack of money, and frequent thrills—not in any particular order. These elements bond us in a way no other avocation can, and we speak a lingo arising from common experience.

One experience I had a number of years ago illustrates this particularly well. I was flying a Piper Navajo C/R, a cabin-class twin that flies like a dream. I was ferrying the airplane from Florida to Nairobi, Kenya, for a friend of mine. I was flying solo and had five 55-gallon fuel drums in the cabin to extend the airplane's range. I had stopped in Naples, Italy, to buy gas after a long flight from Shannon, Ireland, and was headed for Cairo, Egypt.

I trudged into the fixed base operator's line shack and found the owner sitting behind the international prototype of the beat-up old desk. It was clear from his age that he, like me, had flown in World War II—we just flew in different theaters and on different sides. His English was just as bad as my Italian, and as I paid for the expensive gas, we conversed in aviation for a while. He asked me: "Why are you doing this?" I just looked at him, and without my saying anything he nodded his head. He knew why.

Our aviation friends are everywhere: In the 1970s a close friend and I were out flying in his 1930s Spartan Executive and dropped out of the sky at Sid Shannon's airport in Fredericksburg, Virginia. There we found Dick Merrill, of Eastern Airlines fame, feet up on his desk, talking to my old friend, the test pilot Scott Crossfield, who had just dropped in. We all had a great time, each outdoing the other in hangar talk, and, as you can imagine, there were some pretty good stories. I think of that visit every time I walk under the Douglas DC-3 that Dick Merrill flew, now hanging in the Museum's air transportation gallery.

The point to this rambling discourse is that in the course of pursuing our aviation and space avocations, we make friends who have experienced similar interesting and occasionally thrilling things. This bond permits us to engage in a common discourse, regardless of nationality.

Isn't it great that we have a national museum where everyone can come to share memories and enthusiasm with those who want to fly, or who want to learn about flying? In fact, the part of my job that's the most fun is hearing from people whom I have not seen or talked to for a long time. All these wonderful folks tend to show up with amazing regularity, and they make each day an adventure.

But I ask only one small favor: If our paths have crossed and you want to talk, please call ahead or write. I might be out flying.

—Don Engen is the director of the National Air and Space Museum.

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LETTERS

Not Goin' to the Chapel

In response to your story on the kamikaze museum, "Chapel of the Thunder Gods" (Collections, Apr./May 1997): What a load of crap. Next you'll be writing about a memorial to the poor fellows who put on the Bataan Death March.

—Karen R. Gooding
Ridgeland, South Carolina

Ask Me If I Care

I read Tony French's report of having discovered that portions of "High Flight" echo portions of other poems (Letters, Apr./May 1997). Mr. French is, I am sure, a dedicated aviation history researcher, but I feel his comments merit the response "Who gives a darn?"

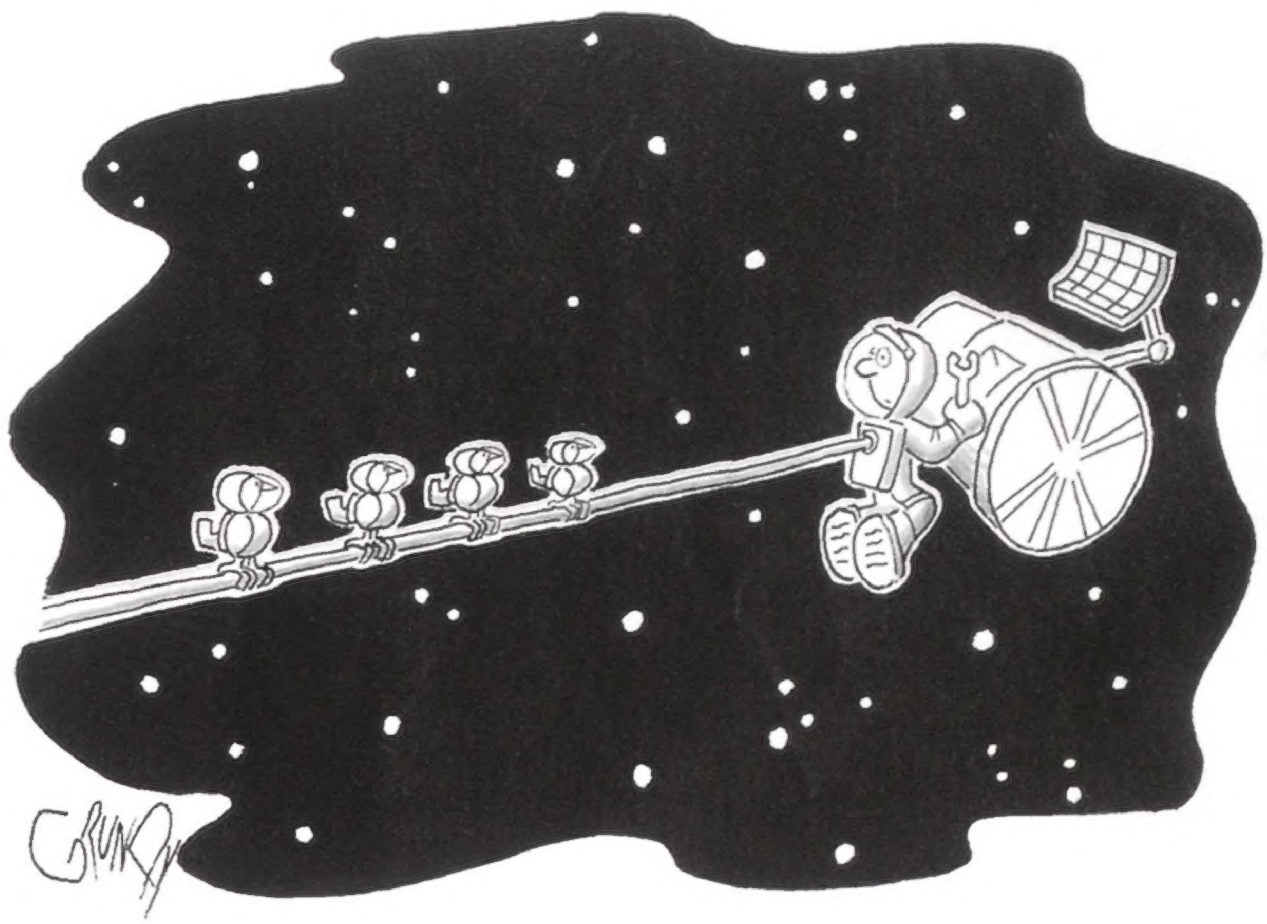
"High Flight" is one of the most inspiring pieces I have ever read. It puts into words the feelings of every pilot who really loves flying. The fact that John Magee may have repeated or paraphrased the words of other writers has little or no bearing on the fact that he was the one who put them all together in wonderful verse form. A pox on Mr. French for demeaning his accomplishment.

—Lt. Col. Donald D. Mitchell
U.S. Air Force (ret.)
Albuquerque, New Mexico

Losing Amelia

Admiral Don Engen refers to March 17, 1937, as the day Amelia Earhart began an attempt at an eastward around-the-world flight ("On Earhart's Trail," Viewport, Apr./May 1997). Actually, on that day, Earhart began a *westward* flight. She landed in Hawaii the next day, then crashed taking off from there on March 20. Her plane was rebuilt, and on May 21, she embarked from California on a second around-the-world attempt, *this* time heading east.

—Jim Tierney
Simi Valley, California



Behold the Beguine

I was dismayed that "Collision Course" (Apr./May 1997) did not include a photograph of Bill Odom's P-51, *Beguine*. The enclosed print (above) was made from film I shot of *Beguine* no more than an hour before the crash.

—Martin A. Snyder
Concord, California

Intruder in My Back Yard

I thought the article "Burial at Sea" (Dec. 1996/Jan. 1997) was very sad, as the A-6 Intruder is my favorite airplane. Instead of making them artificial reefs, I would like to put one in my back yard. I measured and I know it will fit and my dad said it would be OK! I think it would be fitting because they were made here on Long Island and I live between the two old Grumman plants in Bethpage and Peconic.

—Roger J. Von Urff
Age 10½
Dix Hills, New York

Editors' reply: Northrop-Grumman reports that as a result of our article, it has received many requests for Intruders and Intruder parts. Unfortunately, no more are available.

Getting Racing Fans All Revved Up

In "Tanks, Hot Rods, and Salt" (Apr./May 1997), Stephan Wilkinson writes that Bonneville machines made of wing tanks were the fastest open-wheel race cars in the early 1950s. That statement ignores the following accomplishments: (1) Sir Malcolm Campbell ran 253 mph with Napier Lion power and open wheels in 1932. (2) Auto Union and Mercedes-Benz Grand Prix (open-wheel) machines could reach over 200 mph by 1936. Both ran over 270 mph during the 1938 German autobahn record attempts with enclosed-wheel body work. (3) Sir Malcolm ran 301 mph at Bonneville in 1935.

—Donald J. Sherman
(*Air & Space* contributor)
Belleville, Michigan

When Alex Xydias' *So-Cal Special* reached 198.34 mph in 1952, it was not going "faster than any normally aspirated flathead Ford-powered vehicle has ever traveled," as Stephan Wilkinson states. Bill Kenz and Roy Leslie built *777*, a race car with normally aspirated Ford V-8 engines, and set a U.S. landspeed record

(210.648 mph) in it in 1950. The car went on to set landspeed records in each of the next five years.

—Ben Jordan
Denver, Colorado

Stephan Wilkinson replies: I should have written: "Judged against their post-war contemporaries, *tanks were the fastest open-wheel race cars in the world." As for Ben Jordan's letter, it's true that* 777 *went faster than any vehicle ever powered by* two *flathead Ford engines.* So-Cal *went faster than any vehicle ever powered by a single flathead Ford.*

Curse This Wretched Missile Silo

In 1963 and '64, I worked for General Dynamics checking the Master Equipment List in the 72 vertically stored Atlas missile silos ("Bless Our Happy Missile Silo," Oct./Nov. 1996). Every single item of hardware had to be checked for compliance with Army specifications and, if applicable, to verify the make and model number. To identify cables and connectors, I had to crawl around outside the control center and descend 120 feet to the silo floor to check the sump pump. Water seepage wasn't the only hazard; we wore high-top heavy leather shoes to avoid bites from the scorpions and snakes down there.

Once I was checking the sump pump when a hydraulic line burst. The fluid hit a light bulb, shattering it and filling the upper levels with smoke. I tried to get the elevator to come but had no luck, so I ended up having to climb the ladders to the surface. When I finally emerged, I found out that the elevator operator had been the first out and had left the gates open so the elevator was inoperable. I had many choice words for him. We later estimated that I had made the climb in under three minutes. Without the adrenaline rush, I couldn't have done it.

—Hubert F. Cooper
Bonne Terre, Missouri

Whence Cometh the Whifferdill?

Reader Donald J. Bailey's explanation of the origin of the Air Force Thunderbirds' "whifferdill" (Letters, Dec. 1996/Jan. 1997) is almost correct. I flew in the spare and slot positions with the Thunderbirds in 1953 and 1954, and my teammate Buck Pattillo tells me that the term was just a nonsensical word that Harry Evans coined while leader of the Sky Blazers, the aerial demonstration team of USAFE (U.S. Air Forces in Europe). The maneuver is essentially a modified wing-over, rather than a 90- to 270-degree turn. This results in a near-180-degree turn back to the show area. Buck and Bill Pattillo brought the maneuver and term with them after they left the Sky Blazers in Europe and joined the first Thunderbirds team in 1953.

—Robert S. McCormick
Niceville, Florida

Taking Potshots at the Snowbirds

I was irritated by "Home Field Advantage" (Soundings, Dec. 1996/Jan. 1997), in which Phil Scott states that according to conventional wisdom, "in formation flights, size doesn't count. What counts is speed and decibels, and any American present would say the Snowbirds lacked both." True, piloting skills are stretched to the limit at high speeds, but they're also stretched in precision flying in large formations. And if decibels are what count, one need only make low-level Mach passes in a pair of CF-18s.

Mr. Scott should avoid such invidious comparisons. Though the Snowbirds' aging CT-114 Tutor trainers are neither as modern nor as fast (nor as loud) as the Americans' F-16s and F/A-18s, the team has never failed to get my pulse racing.

—Bill Diehl-Jones
Waterloo, Ontario

What's Shakin'?

Reader Stephen Visakay, who deals in vintage cocktail shakers, is seeking information on the specimen above. It shows an airplane marked "AER"; under the picture is the date April 8, 1947. If you can identify what exactly the shaker was honoring, please write us (address at end of Letters section).

Jettison JATO

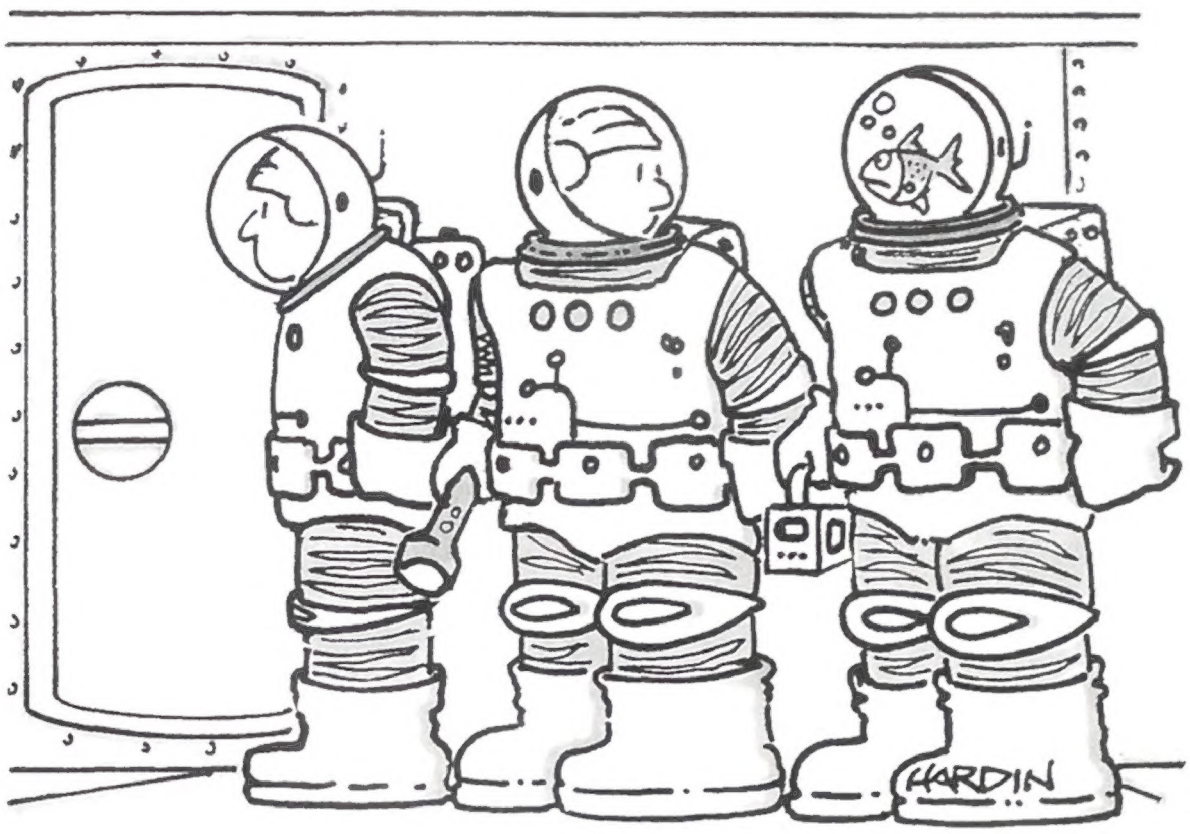
In the Dec. 1996/Jan. 1997 Sightings, you refer to the Blue Angels' C-130 making a "jet-assisted takeoff." I always cringe when I hear that term. Let's set the record straight: Such takeoffs are rocket-assisted.

—John J. Maene Jr.
Hawthorne, New Jersey

A Mail Ritual

"One Good Year" (Feb./Mar. 1997) inspired me to write the following account of a Boeing 247 I remember vividly.

When I was a child in the 1930s, my father's business required him to make an



occcasional trip south to the small town of San Bruno, California. If I was with him and he was finished before 9 p.m., we would sometimes drive a country road through fields and farmland to the San Francisco Airport to see The Airplane. We would drive into a parking lot and stop only a few feet from a low cyclone fence. Along the south side of the parking area was a small frame building with a rotating beacon on top.

A few minutes before nine, a man would come out of the building, light a cigarette, and watch the sky to the south. Presently, a pinpoint of light would appear up there, and the man would crush out his smoke and return to the building. He came back out with a mail sack and a step ladder.

After the plane had arrived, it would stop only 20 or 30 feet from us. The one-man ground crew would open the cabin door, then move to the nose of the plane, where he would set up his ladder. He'd climb up, open the nose compartment door, remove a mail sack, and put in the new one. He would next walk back to the cabin door, and after a few words with someone inside, close the door. My father and I would remain and watch the takeoff. By that time the airport building was dark, the door was locked, and the field was closed for the night.

—Alvin J. Linn
Concord, California

Corrections

Apr./May 1997 "The Human Face of the Space Race" (In the Museum): Due to an editing error, the date of the Apollo-Soyuz docking was given as 1995; the correct date is 1975.

Feb./Mar. 1997 "Company Town": The engine nacelle shown on p. 64 is from the *Graf Zeppelin*, not the *Hindenburg*.

"The Last of the Mohawks": The OV-1 flew its last Korean mission after its State-side retirement ceremony, not before.

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The Raptor Cometh

ERIC SCHULZINGER/LOCKHEED MARTIN

The audience, several thousand strong in the vast Lockheed Martin hangar in Marietta, Georgia, last April, was hushed. The lights were dim. On twin 30-foot-high movie screens bald eagles soared, superimposed over American flags waving in slow motion. "How we name an aircraft is important," the narrator's deep, solemn voice boomed. "Raptors are noble, highly efficient, and lethal birds of prey that use their powers only for survival. Incorporating those noble, lethal capabilities into one machine, we name that machine Raptor!"

Bursts of green lasers pierced the darkness. The floor shook to explosive pulses of sound. Lasers swept overhead. "Lockheed Martin and the F-22 team," the baritone echoed, "proudly present Raptor zee-roh, zee-roh ONE!"

A black curtain opened, revealing a sleek gray fighter. Spears of green light shot from its tail. A rousing Sousa march started up. An Air Force color guard trooped toward the airplane. And suddenly, country singer Lee Greenwood stood before the F-22's menacing nose, belting out: "I'm proud to be an American, where at least I know I'm free…"

"That," marveled a veteran Pentagon correspondent in his fourth decade of covering military affairs, "was more extravagant than usual."

The reason: the rollout of the F-22, the first new Air Force fighter since the debut of the F-16 in 1978. The "next-generation air dominance fighter," in the words of Lockheed Martin and the Air Force, will operate well into the next millennium. The F-22 will be the first aircraft capable of supersonic flight without using its fuel-hungry afterburners, which means long-distance cruising at speeds of over 1,500 mph. Vectoring engine nozzles will make it more agile than any other fighter. Fourth-generation stealth technology will make it nearly invisible to enemy radar. The equivalent of two onboard Cray supercomputers capable of a total of nine billion operations a second will track the type, location, and range of enemy surface-to-air missile sites and the type, location, speed, and direction of enemy fighters, then tell the pilot the most important targets to hit and in what order. The F-22 will be so fast, invisible, and smart that the enemy won't even know what hits it—it will have what the Air Force calls "first-look, first-shot, first-kill" capability. In a pre-rollout briefing Lockheed Martin's Micky Blackwell called the F-22 no less than "a miracle."

There is only one problem with the miracle: total program costs are expected to exceed $70 billion, or $150 million an airplane by the time the last of 438 F-22s is delivered in 2013. In a time of shrinking military budgets, the F-22 program is getting more than its share of scrutiny. No matter. The rollout pushed all the patriotic goosebump buttons, and for 90 minutes a cool new warplane made it feel like, as Air Force Chief of Staff General Ronald Fogleman exhorted the crowd, "a great day for America."

—Carl Hoffman

Windows for Rémy

Few would think it a heroic act to lay flowers on a grave. But in German-occupied France in World War II, a simple remembrance became an act of open defiance.

On August 2, 1944, Lieutenant Houston Braly and his fellow 383rd Fighter Squadron pilots were flying P-51s on a search-and-destroy mission north of Paris. The Mustangs pounced on a heavily camouflaged ammunition train at Rémy. On their second pass, the train exploded with enough force to gouge a trench 40 feet wide and 10 feet deep and blow the

roofs off several houses. Every stained glass window in Rémy's 13th century St. Denis church was reduced to shards. Debris hurled by the exploding train sheared the tail off Braly's Mustang, which plowed through trees and came to rest against a stone house.

After removing Braly's body from the wreckage, villagers wrapped it in his parachute and hid it in a stable. As word spread throughout the town, Rémy's citizens began to bring flowers. Even after the Germans found the body and ordered that it be quickly and unceremoniously buried, flowers continued to appear. A German commander threatened that any villagers caught tending Braly's grave would suffer dire consequences. In a few weeks, American forces entered Rémy and found Braly's grave, marked with a bent propeller blade and covered in blossoms.

Over the years, the scars of war were smoothed over in Rémy, but the church's clear panes made a mockery of the majestic window openings where fine stained glass once scattered sunlight in brilliant colors. Stephen LeaVell, a United Airlines captain and aviation history enthusiast, stumbled upon the story of the simple tribute Rémy's villagers had paid to an unknown American airman. LeaVell was researching the history of the 383rd at the request of his neighbor, Manuel Casagrande, who was one of Braly's squadron mates. "When I finished reading the story, I was in tears," LeaVell says. "At the time, I had a son about the same age as Braly."

By unearthing the story, LeaVell provided the surviving members of Braly's squadron with a way to thank the villagers both for their courage and for their reverent treatment of a fallen comrade. The Windows for Rémy foundation was born in 1995.

U.S. AIR FORCE

GEOFF CHESLER

As they heat up near the sun, comets reveal the invisible. Hale-Bopp shows two distinct tails—a whitish one made of dust and a blue one formed when charged particles (ions) from the comet spiral around the sun's magnetic field. The dust tail shines in reflected sunlight and points away from the direction of motion; the ion tail glows on its own and points away from the solar wind. Last April, European astronomers using the Isaac Newton Group of Telescopes in the Canary Islands discovered a third tail, consisting of sodium atoms and invisibile to the naked eye.

LeaVell and former 383rd members hope to raise $200,000 to replace the stained glass. As of last April, the group had amassed about $93,000. Member Gordon McCoy, a retired banker, says he used to be jaded about large amounts of money, but raising the funds for Rémy's windows a little at a time gives him a renewed appreciation for six-figure totals. "We have some people who send us a $25 check every month," McCoy says.

Any restoration of the windows must be approved by the French government, which has awarded the church historic-building status. LeaVell and foundation members hope that red tape, which accumulates as thickly in France as it does in the United States, can be cut soon so that Rémy's windows will again shine with colors as bright as those once laid upon a flier's impromptu grave.

—John Sotham

Going Inert

Amarillo, Texas, calls itself "the helium capital of the world." Most of the world's helium reserves percolate through porous rock in vast fields that extend from Amarillo northward into Kansas. Amarillo even built a monument to the helium atom; looking like a toy for a young giant, it consists of four metal tubes containing time capsules to be opened over the next thousand years.

But Amarillo may have to give up its prized title next year. The helium will still be there, but under a law passed last year, the federal government will close its production facilities in and around Amarillo and begin selling off more than 30 billion cubic feet of helium, enough to supply the world for about 10 years at current consumption levels.

"A lot of folks in Congress felt this wasn't a function for the government anymore," says David V. Hayes Jr., engineering chief for the Bureau of Land Management Helium Operations in Amarillo. "The private companies wanted

BUREAU OF LAND MANAGEMENT

TOYSMITH

Attention prop heads: Toysmith, manufacturer of the Walk About line of aviation toys for children, has produced a three- by six-foot Runway Rug for adults, according to a press release. The Runway Rug comes in Standard, Executive, and Industrial Strength, with custom runway numbers available on the latter. Call (800) 687-9060.

us gone. At first there wasn't any profit in helium. Later on, private industry figured out how to make money. That's just the way the world works."

The government opened a helium processing plant in Amarillo in the 1920s and later added the Exell plant north of town. For many years these plants (and a third in Oklahoma, which closed in the late 1980s) produced almost all the world's helium. During World War II, helium buoyed the Navy and Coast Guard blimps that patrolled U.S. coasts and was considered so vital to the war effort that barbed wire and guard towers were installed around the plants.

Barbed wire and "No Trespassing" signs still encircle the Amarillo plant—which looks more like a prison than a supply depot for blimps and mylar balloons—even though it serves mainly as a pumping station and chemistry lab and not a refinery. Exell, which sells only to government agencies, is the country's sole supplier of gaseous helium, which NASA and the Department of Defense use to purge rocket engines and pressurize fuel tanks. BLM operations account for just 10 percent of total domestic helium production.

Under the new law, Exell must close by April 1998. Equipment at both Exell and the old Amarillo plant will be offered to federal agencies and the leftovers sold at auction. All but one billion cubic feet from BLM's huge helium stockpile, which is stored in the Cliffside field northwest of Amarillo, must be sold off by 2015. "Slowly but surely, the field will be depleted of government helium," says Hayes.

BLM will maintain a small staff in Amarillo to oversee the storage field and a network of pipelines that connects helium producers, but most of its employees will lose their jobs. "Many people have been working at one of our plants for almost their whole lives," Hayes says. "There's a lot of resentment. But for a long time, other people felt we didn't have a function here. It just finally happened."

—Damond Benningfield

It Keeps Going and Going and Going...

At 11:45 a.m. Pacific Standard Time on March 31, 1997, a quarter-century after it left Earth, Pioneer 10 got a call from NASA telling it not to bother to phone home anymore. No one is listening.

The last in a series of research spacecraft launched after the Soviet Union's Sputnik shattered illusions of U.S. technological supremacy in 1957, Pioneer 10 scored several firsts. "It was the first to cross the unknown asteroid belt, somewhat surprisingly without significant damage," said Pioneer project manager Lawrence Lasher. "It survived and measured the radiation belts of giant Jupiter and gave us our first views of it and of its moons Io and Europa—the latter discovered only last April to be a sea of ice—and Saturn. And it was the first to leave our solar system. All by a craft designed for a 21-month mission to Jupiter." With only one of its 11 scientific instruments still operating, Pioneer 10 is no longer cost-effective.

At NASA's Ames Research Center in Sunnyvale, California, Lasher and a dozen officials and engineers gathered to symbolically dim the Pioneer Mission Control office lights, then thank the tracking crew at NASA's Deep Space Station near Madrid, Spain, as they turned their antenna away from Pioneer. Television news camera crews jockeyed for position to capture an image of a modest-size computer monitor with squiggly lines going flat, like a scene from "ER."

Pioneer 10 had been sending data from its eight-watt night-light-size radioactive power source for more than 9,000 days. When the last signals were received on Earth nine hours and 10 minutes after they were sent, they had dissipated to just 2.5 billionth of a trillionth of a watt. Pioneer was still sending useful data, recording the intensity of galactic cosmic rays in the outer heliosphere, the region that reflects the influence of the solar wind.

At 6.2 billion miles, the TRW-built craft is now farther from Earth than any man-made object has ever been. The probe is expected to have its closest encounter with a star in about 30,000 years. But "Star Trek" fans believe it has a mere 290 years of existence left. It seems the Klingon warrior Captain Klaa destroyed it in 2287. No one at NASA buys that, of course—although Lasher did mention it.

—Bob McCafferty

NASA/AMES RESEARCH CENTER

TONY LANDIS/NASA

"It's a new type of high-shock landing gear designed by a guy named Coyote at the Acme company." Workers position an F/A-18 in a permanent takeoff on a pole at Lancaster Municipal Stadium in California, appropriately named The Hangar and home field for the Lancaster Jethawks, a farm team for the Seattle Mariners. "NASA 842" had served NASA's Dryden Flight Research Center as a chase plane since 1987 and was put out to pasture—on loan to the city of Lancaster—last March.

High-Speed Seedlings

Moshe Alamaro has a dream: He wants to fly to the world's remote forest regions and bomb them back into the Stone Age. Actually, Alamaro, a candidate for a Ph.D. in mechanical engineering at Massachusetts Institute of Technology, wants only to restore and re-seed the forests back to their Stone Age lushness, using cone-shaped "bombs" with "charges" consisting of tree seedlings.

"Many locations once supported forests, but because of climate changes or clear-cutting, those places don't have forests today," Alamaro says. "The question is how to plant the trees there. The solution is to drop tree seedlings from airplanes in biodegradable containers."

But seedlings are delicate creatures. In the United States, government agencies and private firms replant forests gently by hand to ensure their survival. In fact, Alamaro adds, a seedling dropped to the floor from a chest-high altitude will declerate at a crushing rate of several hundred Gs. That's why he and an informal team, which includes James Kain, the brains behind some precision-guided smart weapons, are using the MIT wind tunnel ("It looks like a nursery in there now," Alamaro says) to find the perfect shape for their tree bomb container. "In our case the tree would take a few inches to penetrate and take a few inches to decelerate," says Alamaro. "Nothing would happen to the tree—we are sure about that from the mechanical point of view."

Kain and Alamaro will first pack the seedlings in bomb cases that are not only aerodynamic but also biodegradable, pre-fertilized, moisture-absorbing, and vermin-resistant. They will then shoot the cases from the cargo bay of a low-flying transport like a C-130 Hercules using air cannon similar to those used at tennis courts. By coupling such cannons with global positioning data, Kain says, "It's like walking through the front yard and saying, 'I want to put a tree here and here and here.' "

Though the pair have attracted attention, they have no firm customers. But touting trees' ability to absorb greenhouse-effect gases, produce oxygen, and prevent erosion, the two are looking to global entities like the World Bank and the United Nations' Food and Agriculture Organization for a little seed money.

—Phil Scott

Tweaking the Tappets

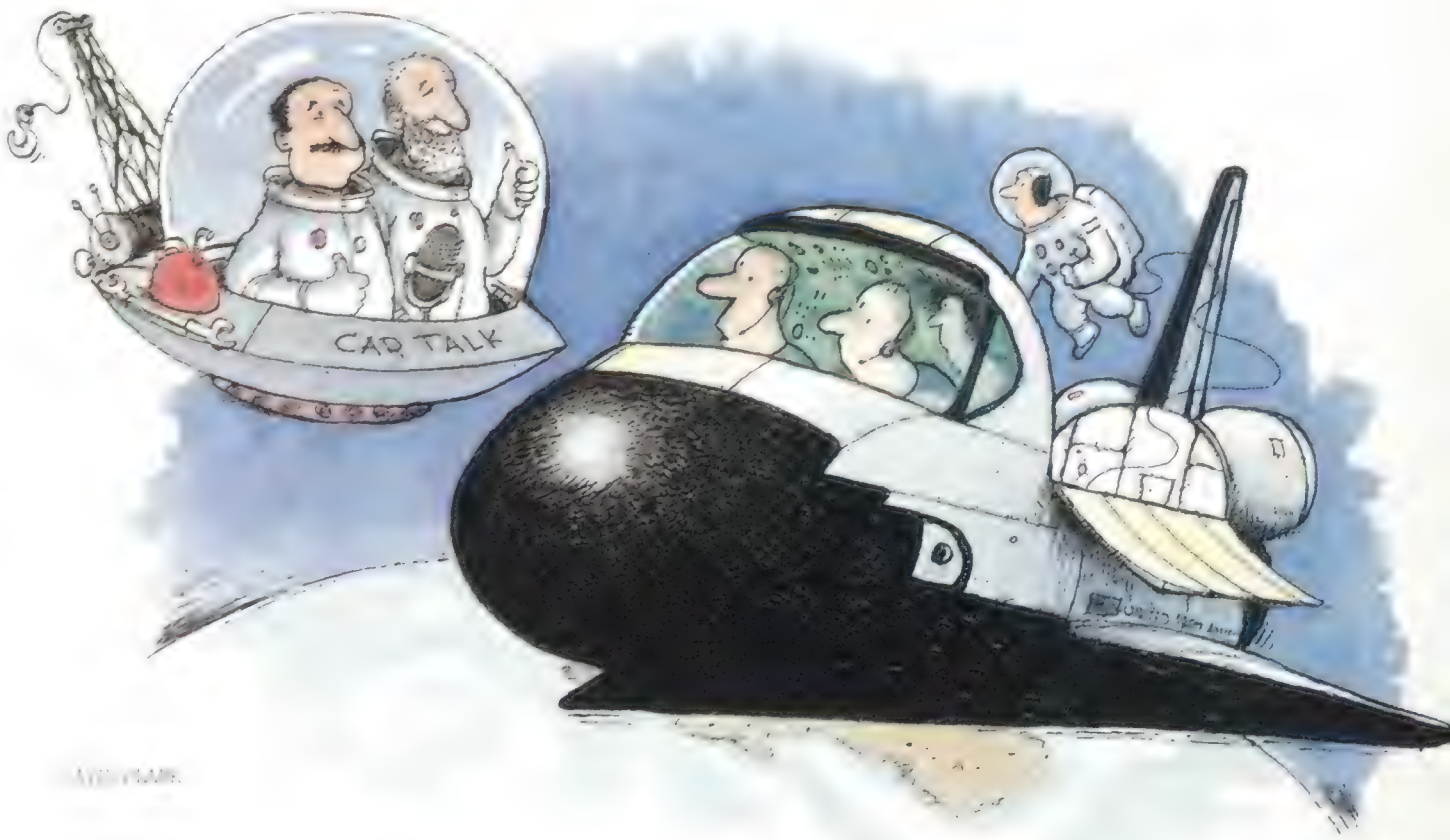
As hosts of "Car Talk," National Public Radio's automotive advice show, brothers Tom and Ray Magliozzi—who call themselves the Tappet Brothers—are used to tackling difficult mechanical diagnoses. But last January they faced a puzzling query. The caller, who identified himself as "John from Houston," said he had a problem with a government vehicle. "It starts great, accelerates really well," he began. "It runs incredibly rough, though, for about two and a half minutes." After that, he continued, "it runs smooth, but only for about six and a half more minutes. At that point, the engine dies." Furthermore, said John, he had experienced the same thing in two identical vehicles.

By this time, Tom and Ray were a little suspicious. There was something peculiar about John's voice that made the brothers doubt that this was an average long-distance call. Ray said, "You sound like Tom Hanks saying, 'Houston, we have a problem.' Where are you calling from?"

"Just a second, let me look," came the answer. "I'm about 200 miles north of Hawaii." The brothers broke up laughing as their suspicions were confirmed. "John" was shuttle astronaut John Grunsfeld, calling from *Atlantis*, which was docked to the Mir space station. The call was relayed via NASA's Tracking and Data Relay Satellite System. When Tom asked Grunsfeld how fast he was going, the answer set a "Car Talk" record: "About 17,500 miles an hour." Grunsfeld added, "The odometer on this thing reads about 60 million miles." But the ride, he noted, was very quiet.

Grunsfeld said that in 1977, as a student at the Massachusetts Institute of Technology, he used to bring his Sunbeam Alpine to the brothers' garage. Ray joked, "The last time you were there, you didn't pay your bill," and said he would send a reminder—if Grunsfeld could provide a forwarding address. A moment later, as *Atlantis* and Mir sped onward, Tom offered a summation rife with understatement: "That's the most interesting call we've had in a little while."

—Andrew Chaikin



Dodging a Bullet

If you were a pilot or a weapon systems operator in a McDonnell F-4 Phantom II during the Vietnam war, your first indication that you were nearing an installation of SA-2 surface-to-air missiles was a signal chirping in your headset. "You could hear [the search radar] trying to find you," recalls Dean Failor, a retired Air Force lieutenant colonel who flew 377 combat missions as a weapon systems operator between 1970 and 1973. The Phantom's RHAW (Radar Homing and Warning) gear acted like the "fuzz buster" motorists use to detect a highway patrol's radar: It was tuned to the frequencies of the missile's search-and-control radar and announced the detection of the signals with an audible tone. Once the missile radar acquired its target, it switched to a tracking mode, and the chirping in the RHAW gear increased to what Failor and his colleagues called a "rattlesnake" signal. "That's when you knew they had ya," Failor says.

They actually got very few. Of 9,000 SA-2 missiles fired in Vietnam, no more than 160 found their targets—small comfort to the airmen in those 160 airplanes brought down by what NATO designated the SA-2 "Guideline" and everybody else simply calls SAMs. They are the most widely used surface-to-air missiles of all time, with tens of thousands deployed in the Soviet Union and its client nations during the cold war. This makes them very interesting to U.S. flying services and to the curators of the National Air and Space Museum.

"It's one of the most significant artifacts of the cold war," says space history curator Frank Winter of the SA-2 missile now being cleaned up in the Museum's Paul E. Garber restoration facility. "A missile of this type knocked down Powers," Winter says—as in Francis Gary, the CIA pilot shot down over the Soviet Union on May 1, 1960, when an exploding SAM shattered the control surfaces of his U-2 spyplane. (Powers ejected, but he and the espionage equipment and film in his crashed airplane were captured.)

COURTESY DINO BRUGIONI

SAMs didn't have to hit the bull's-eye to do damage. This missile's proximity fuse exploded it close enough to an RF-4C to destroy the aircraft.

Winter hasn't been able to confirm the origin of the Museum's SAM, which arrived without a nametag from the Naval Ordnance Center in Indian Head, Maryland, in May 1985. "The donor was not at liberty to inform us how it was originally acquired," says Winter. But the curator has a pretty good idea that the SAM belonged to the Egyptian armed forces, was captured by the Israelis in the 1973 war, and was turned over to U.S. intelligence agents.

The mystery makes the SAM's restoration something of a detective job for Garber restoration specialist Bobby Padgett, who found a small amount of sand in the missile when he first took it apart. It is in pieces now in a corner of the warehouse-size workshop in Silver Hill, Maryland. Its nine-foot booster stands near its 25-foot second stage (minus the nose cone), which rests on sawhorses.

The second stage originally had four large stabilizing fins, but two are now missing, and Padgett is fabricating replacements from aluminum. The original fins were each made of two identical pieces of magnesium riveted together. They look heavy, but Padgett easily lifts one and inserts its flanges into slots in the missile body. "Magnesium is lighter by half than aluminum," he says. "Every pound they saved in structure could go into payload."

That would be the 400-pound explosives and detonator package, which rides behind the nose guidance compartment and which was missing from the SAM when it arrived at Garber. SAMs were equipped with proximity

fuses—little radio receivers and electronics that could determine the distance to the target and command detonation at, say, 50 feet. The distance varies depending on the model, according to Steven Zaloga, author of *Soviet Air Defence Missiles*. "You're very unlikely to directly impact the aircraft, especially because it's moving toward the missile at 600 mph and the missile is moving toward it at about the same speed," Zaloga says. "Also, SAMs are not very maneuverable. They have very small control surfaces. The proximity fuse gives them a larger lethal area."

The SAM's poor maneuverability—earning it the nickname "flying telephone pole"—partly explains the relatively low number of kills it scored in Vietnam. Fighter pilots could outfly them. But to do that, they first had to let go of their bombs, so even though SAMs scored few hits, they did succeed in defending targets.

"We'd wait for the launch," remembers Dean Failor. The missiles were hard to see in the daytime, but at night pilots could spot the reddish glow from the booster, then a silvery white plume from the sustainer engine. "We'd turn the aircraft so the missile was either at 10 or 2 o'clock in the canopy, then we'd just drop," Failor continues. "We'd put on full afterburner, put the stick forward, and dive. The point was to get as much energy—we'd say 'Get as much smash as possible.' It would follow us down. At the last minute, we'd roll up and into it. And the missile couldn't turn. At that point it would try to follow, but it would tumble out of control.

"And that'd be okay, if you had only one missile shot at you."

Bobby Padgett is holding a long, skinny slotted metal tube. It is one of eight strip antennas that ride under flat fairings bolted at intervals around the circumference of the missile near the nose. The antennas were designed to pick up guidance signals from the Fan Song radar, the ground-based brains of the SAM system. "They call it a 'beam rider,' " says Padgett. Coaxial cables connect the strip antennas to a small rudimentary computer, which sends electrical signals to mechanical actuators linked to the guidance fins. "So the beam actually steers it," Padgett says. Versions of the Fan Song radar used in Vietnam could track six aircraft at once and guide up to three missiles directed against each target.

Dean Failor says it's that second or third SAM that gets you: "After you've avoided the first one, you've dissipated a lot of energy." A common expression for that situation is "out of airspeed and out of ideas." One night Failor and his pilot dodged one, broke hard when they saw a second, and were headed out over the ocean when a third SAM exploded—close enough to illuminate all three of the Phantoms in the formation.

When McDonnell Douglas equipped the F-4s with increasingly sophisticated electronics to deceive the Fan Song radar, the already underwhelming performance of the Soviet-supplied missile systems worsened. The SAM had been designed to play the role in the Soviet Union that the Nike Hercules was to play in the United States: missile defense against a swarm of big, relatively slow, high-flying strategic bombers. The SAMs' performance against smaller, maneuverable supersonic fighters in one of the sideshow theaters of the cold war was nothing to write home about—unless you happened to be in one of those fighters that got away.

—Linda Shiner

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY: (202) 357-1729.

June 4 Exploring Space Lecture. John Mather, of NASA's Goddard Space Flight Center, will share his insights on the design of the successor to the Hubble Space Telescope. Einstein Planetarium, 7:30 p.m.

June 14 Model Airplane Workshop. Participants can catch a glimpse of the Museum's extensive model collection and learn how to build and fly a radio-controlled model. For children ages 10 to 13 accompanied by an adult. To register, call (202) 786-2108. Lower level briefing room, 10 a.m. to 1 p.m.

June 14 "Women and Flight." This new photography exhibit features 75 black-and-white portraits of 37 contemporary women aviators by Museum staff photographer Carolyn J. Russo. Special Exhibitions Gallery.

June 23–September 1 Two new evening features have been added to the Langley Theater's schedule: *The Magic of Flight* at 5:45 p.m. and *Whales* at 6:30 p.m. For more information, call (202) 357-1686.

ERIC LONG

The Solo Spirit *gondola of distance balloonist Steve Fossett touched down for a two-month visit at the National Air and Space Museum last spring. Fossett, who last January attempted to make the first nonstop balloon flight around the world, ran out of fuel and was forced to land in India. He plans to try again for the round-the-world record, which will take about 18 days.*

Lifted by a combination helium-hot air balloon, the 1,200-pound gondola is constructed of a Kevlar-carbon composite and is powered by 600 pounds of lithium batteries. As for the comfort of its passenger, the unpressurized Solo Spirit *is decidedly low-tech: a cabin temperature of 40 to 55 degrees Fahrenheit, an oxygen mask for breathing at high altitudes, a diet of MREs (meals ready to eat), and a bunk for sleeping. What about a bathroom? The balloonist's Web site describes it as "a bucket."*

Choices

No pilot ever forgets that his calling carries with it the risk of profound loss. Calculations of risk are a fundamental part of flying, not only on days with turbulent skies and long-distance flights over unfamiliar regions, but with every act that moves an aircraft into the fragile world of flight. The afternoon sunshine, the pressure of the wind, the grass of the runway are felt so fully, understood so completely by a pilot precisely because so much of life itself is weighed at every decision point.

This calculation is not a dominant thought process. If it were to become so, the flier would have to stop flying. Instead it is a gentle river of awareness that flows over, under, and around every simple action, a dispassionate analysis of what might lie ahead and whether the likelihood of error or failure or the unexpected is sufficiently great that what is planned next should be reconsidered. It becomes habitual, instinctual.

"I remember Karl climbing lithely into the front cockpit, his delighted eyes framed by the leather helmet."

The airplane creaks in the wind as I walk around it before flight and I sense how light and how fragile it is, yet how strong and resilient. Engine running now, I climb into my seat. The steel buckle of the seat belt clicks solidly.

I push the throttle forward slightly and the pulse of the machine is fully transmitted to my body as the engine vibrates, the fabric and steel shell surrounding me resonates, and the tires begin to roll across the uneven earth. The rhythmic rise, twist, and fall begins to tell me about the land even as my eyes move quickly to the windsock and trees to read again the message of the wind and sky.

And so the pilot moves through time, action by action. Yes, I will start the airplane. Yes, I will add power to taxi. Yes, the grass and the wind and the sky and the airplane are acceptable today. Yes, I will choose to take off. And so a flight is begun. And so, my friend Ed reminds me later, lives are lived.

Tonight I am trying to understand all of this, because earlier today I made decisions not for myself but for my son. This afternoon, in the brilliant sunshine of early summer, my decisions moved him through a point in space and time that proved to be the place, just seconds later, where two airplanes collided and four lives ended.

PAUL N. UHLIG (2)

I remember waking Karl this morning. His hair was tousled and his face was sweet and he smiled at me and began stirring. Karl, his brother Bobby, Ed, and I were on the road by seven so we could be in Bartlesville, Oklahoma, by 10 for a homebuilt Hatz airplane forum at Biplane Expo '96.

I remember Karl's enthusiasm. It surprised and pleased me that he could sit still for the hour-long session and that he seemed genuinely interested. We walked over to the flightline and found three Hatz biplanes. He reminded me that when he was here two years ago he had been afraid to take a biplane ride, but his older brother Paul had gone on one. This year, Karl said he would like to have a ride. This year, he was not afraid.

A friend was giving rides in a red and cream Hatz and another offered rides in his yellow Stearman. The big green New Standard biplane that Paul had flown in was lumbering regularly into the air with paying passengers. We walked by the line of customers, but cash was short and the line was long. The Hatz was up, though, and we went to see about a ride.

I remember Karl's shy but determined handshake with his pilot, cementing the agreement, and the pleasure we felt in the chance to give a kid an airplane ride. I remember the bright sunshine and the scattered clouds over the green hills west of the field. I remember Karl climbing lithely into the front cockpit, his delighted eyes framed by the leather helmet as he stretched upward to see over the edge of the cockpit, even with a folded leather jacket boosting him several inches.

I remember most of all the thought processes going on coolly, quietly, as I reviewed the risks and the decision to fly. A known airplane. An experienced pilot. A beautiful day. More traffic than I would

"And of course there are the pictures of the KR-31, of Karl. Will they tell me something I don't understand now?"

like, but orderly and generally cautious. Probably enough fuel (I couldn't tell). A confident and happy child smiling at me and enjoying his moment of courage and adventure. What if they lost power right after takeoff? What about that damn Mustang making those high-speed low passes? Could Karl slip out of the seat belt, fall out of the cockpit? Is it okay for this child, who trusts me, to fly in this airplane, at this moment? Yes, it is okay.

I stood to the side of the Hatz, ahead of the wing, and made sure people stayed clear of the propeller. I signalled to Karl's pilot that a safe start was possible and watched his airplane start, then taxi carefully into line for takeoff.

I remember the two green airplanes that taxied with the Hatz, the Kreider-Reisner 31 with its OX-5 engine clattering, the passenger smiling and adjusting helmet and goggles. I remember the man in the stocky and powerful Waco who weighed too much, whose yellow hair blew straight behind him, and the beautiful woman in the front. He taxied aggressively and very fast, and I wondered how long she had known him, and about the chemistry of man and woman and airplane.

Karl's airplane took off, then the KR-31 took off, and I caught each in the viewfinder. The Waco took off and flew low and fast and then zoomed into the sky. I had no fear, no sense of what was going to happen. Just a cool analytical sense that the Waco pilot was not being careful enough and wow, that Mustang came by fast again.

I don't remember much else about the next 10 minutes except the Waco came by for another pass and he started too high and then turned sharply, diving for the runway, and it seemed impossible that he could crash but geez he had to pull out of that diving turn and he didn't have much room. Somehow he got straightened out and went roaring by five feet off the grass and zoomed into the sky again.

A few minutes later Karl's airplane was on final approach and behind his were about four airplanes. Soon the red and cream Hatz taxied up and started to turn onto the grass where we were standing. I remember thinking about Karl and how to greet him when I sensed that something had changed. Behind Karl a plume of black smoke was climbing quickly into the sky and a siren sounded as an ambulance moved from behind us in frantic lurches toward the taxiway. We turned toward each other and someone said, "I just looked up and saw it, saw them hit, and wings came off both airplanes and they just spiralled down."

We looked at each other and at the sky and at Karl's airplane as the engine stopped and seatbelts were released. Karl and the pilot climbed out and we all stood there, not knowing how to protect Karl from the emotions or how to somehow keep this calm. "There was a crash, Dad," Karl said. "They said on the radio that there were no survivors."

I knelt by my son and saw that his eyes were searching mine to see what all this meant. I did the best I could. I said, "Flying is wonderful, but it's very serious too, and this reminds us that we always have to be very careful." His eyes stayed calm and I think he understood.

I am writing this tonight, remembering the Waco and the beautiful green KR-31, remembering the passengers and the pilots as they taxied past me, wondering whether we get any warning at all when death is about to surprise us, and feeling a sense of disbelief and confusion about how these things happen and how final they are.

But I am looking at death from outside. I suspect most of us will not worry about the finality when it is our turn. I suspect the experience is so interesting that we won't even think about what might have been, especially if we have a sense of the connectedness of life and its ongoing nature.

And of course there are the pictures of the KR-31, of Karl. Will they tell me something I don't understand now? How could I have looked at Karl's picture if it had been his airplane that had spiralled to Earth without a wing?

I will fly tomorrow, and I will remember all of this. I will rejoice that I was taught to fly and to love life.

—Paul N. Uhlig

Hyperventilation

RICHARD THOMPSON

A few years ago a safety engineer at NASA's Kennedy Space Center was sifting through his mail when something caught his eye: a safety alert for "explosion-proof" flashlights. Some of these flashlights, the warning stated, had slipped past the manufacturer's quality control and couldn't be guaranteed to be explosion-proof.

The engineer, new on the job, didn't know that the term "explosion-proof" is applied to devices that have been hermetically sealed, making them safe to use in an explosive atmosphere. Guided by an entirely different interpretation of the message, he grabbed the phone, called the bomb squad, and told them to get their defusers ready: A number of flashlights at the space center were about to blow.

At least that's the way legend has it. But considering the nature of the KSC safety engineer's job, the story is entirely believable. As a graduate of innumerable safety classes during my 12 years as a payload test engineer at KSC, I can attest that these safety engineers know better than anyone that the rocket business can be extremely hazardous to your health. Who can blame them if they react accordingly? After all, it's their job to protect the thousands of professionals at the center who, during the course of a day, work with an astonishing array of substances capable of depriving a person of life or limb. Need proof? Go check out NASA's stockpile of caustic solvents and ordnance devices, all labeled TOXIC, VOLATILE, FLAMMABLE, and LETHAL.

While each of these materials commands respect, there is one ugly customer that is the most fearsome of the chemicals stored at the rocket ranch. It's a class called hypergols. The space shuttle uses two in particular, nitrogen tetroxide and monomethyl hydrazine, names that strike terror in the hearts of safety inspectors.

These two substances are useful because of one interesting property: Mix them together and they explode. This, of course, is why space rangers think the compounds are so attractive. Hypergols don't care whether they're sitting on the launch pad or orbiting Uranus. The equation remains the same—mix them and they explode. Propulsion engineers get misty-eyed when they talk about hypergols.

The technicians who load these fuels tend to get emotional too, but for a different reason. Hypergols have a special affinity for human skin. Just the briefest exposure to hypergolic vapors means a frantic strip and a 20-minute scrub in a safety shower. Afterward, you get shipped to the hospital to see if something can be done to stop that pesky hemorrhaging in your lungs.

The message safety engineers try to get across is: Hypergols Are Bad News. Watch for nitrogen tetroxide's telltale reddish vapor cloud and its pungent, sweetish smell. You won't see hydrazine—it's invisible. But be alert for a fishy, ammonia odor. Get out of the building, check the windsock, and run upwind from leaks. And don't be afraid to report any suspicious clouds or odors. Better to be safe than real sorry.

About five years ago one group of technicians took that message to heart. While installing a rooftop satellite dish, they noticed a fishy, ammonia odor. But as far as anyone knew, monomethyl hydrazine had never been stored anywhere near the building. Perhaps, as their supervisor suggested, the techs had fabricated the story in order to get off a hot Florida roof in August.

Fabrication or not, you don't ignore reports of hypergol leaks. Engineers pulled out their electronic sniffers, donned protective suits, and headed for the roof.

When the equipment showed no trace of the deadly vapor, team members doffed their masks. Sure enough, there was a fishy, ammonia odor, which the engineers quickly traced to a vent leading from...the men's room.

The investigation summary stated that KSC workers were safe for another day. But the report stopped short of classifying the fumes as non-toxic, non-volatile, non-flammable, and non-lethal, an omission that tends to support the claim made by one investigator: that the rooftop gas may have been a fuel source that NASA had overlooked. If that's the case, engineers may be thankful they had not peered into the vent with one of those non-explosion-proof flashlights.

—Dan Kovalchik

I FIND THE GREAT THING IN THIS WORLD
IS NOT SO MUCH WHERE WE STAND. AS IN WHAT DIRECTION WE ARE MOVING. -Oliver Wendell Holmes, Jr.

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TAHOE
LIKE A ROCK

THE END

by Joseph Bourque

Photographs by Robb Kendrick

And the beginning. When Bergstrom Air Force Base closed after 51 years, the memories—and a 12,000-foot runway—remained.

After half a century of service, Bergstrom Air Force Base was unexpectedly slated for closure. Now the 3,100-acre parcel of land (below and left), home base for B-52s and RF-4s at the height of the cold war, is being steadily transformed into an international airport. A new control tower stands in the distance, even though an old one (foreground) has yet to come down.

Just eight miles from the steps of the Texas state capitol, Austin-Bergstrom International Airport is rising from the dust and splinters of what used to be Bergstrom Air Force Base. There's very little left of the old, and not enough of the new, to relieve the desolation.

But if you look beyond the barrenness, you can spot hints of what Bergstrom once was. The distinctive "Christmas tree" configuration of the concrete pads where B-52s once waited on alert is still visible from the air. The gaps between the pads have been filled to form the apron for new air cargo facilities, but the difference in coloration between the old and new concrete reveals a ghostly outline of Bergstrom's former self. There's also the base's 12,250-foot runway, built to sustain the pounding of the former Strategic Air Command's heavy bombers. It's been refurbished in spots, grooved to improve traction, and fitted with new lights and instrument landing system equipment. Soon it will launch and receive commercial airliners.

These remnants, however, are less significant than the thousands of people whose lives intersected with the air base's 51-year presence. History and memories are present amid the swirl of emotion, determination, imagination, petty feuds, and, ultimately, cooperation that have accompanied the transformation of a shrinking military facility into a bustling new airport.

Irene Burton Gallet was among the first Civil Service employees assigned to Bergstrom soon after it opened on September 12, 1942. She remembers when the base was just tents in a cotton field, and later, tarpaper shacks. "We built the base around our chairs," she says. After 50 years, first as assistant to the base commander and last as director of administration, her retirement came within a few months of the closing. "I haven't been able to go back there,"

she says. "It would be like going to see a friend who died. It's a heartache I can avoid. I'll go when the new airport is open."

The familiarity of Gallet's sentiment does not make it any less touching. Dozens of U.S. military bases worldwide are closing, with the inevitable consequence of disrupted lives. Surrounding communities lose jobs, and some must restructure, or at least realign, their economies. Since major military installations provide most of their own services, closing a base is the equivalent of wiping a small city off the map.

Gallet is one of the luckier few in that the ending of her career coincided with the disappearance of her lifelong employer. For most people, a closing is more traumatic, and it's usually a surprise. Few expected Bergstrom to appear on the 1991 Base Realignment and Closure list. There was too much aviation history here. Many people still remembered the day in 1943 when a fleet of 50 C-47s, on their way to the war in Europe, flew low over Austin and landed at Bergstrom for training. Later, Bergstrom's F-84s went to Korea, its RF-4 reconnaissance jets flew to Vietnam, and its B-52s stood at the ready during the Cuban missile crisis. And when the base's Air Force Reserve facility (spared in 1991) appeared on the 1995 closure list, the last vestige of Bergstrom's military mission vanished.

Jim Zwernemann spent his entire 30-year professional career as a civilian engineer at Bergstrom, and since he was within two years of receiving a full pension when Bergstrom turned up on the closure list, he felt a sense of dismay coupled with disbelief. "It seemed like this base would never go away because Lyndon Johnson used it as a stop whenever he went to Johnson City," he says. "So the base was kept in absolutely pristine condition. People who had been all over the world would tell me that this was the most beautiful place they'd ever been stationed."

But money is a powerful motivator. While the cost of closing Bergstrom and the reserve facility would total $94.1 million (including environmental cleanup), millions more would be saved by shutting the base down.

The builders of the new airport are planning a 9,000-foot runway parallel to the old one (top).

Irene Gallet, who retired from Bergstrom after 50 years of employment, says: "I haven't been able to go back there. It would be like going to see a friend who died."

The closing, which began in earnest in June of 1992, was directed by the Air Force Base Conversion Agency. Set up by the Air Force to oversee base closures, it is staffed by Civil Service employees. The agency appointed Dick Pautz site manager. His group worked with 2,000 or so Air Force personnel under the command of Colonel Scott Madole—all that remained of the nearly 10,000 military and civilian employees assigned to Bergstrom at the height of its reconnaissance mission, which occurred in the mid-1980s.

During that time, the base was home to four squadrons of RF-4s—about a hundred aircraft. But as the Air Force shifted from manned reconnaissance airplanes to remotely piloted vehicles, the RF-4s were gradually retired. By the time the closing was announced, Bergstrom was allocated only 18 of the reconnaissance jets (the base's B-52s had left in 1966). The remaining RF-4s gradually trickled away, all of them flown by the squadron pilots to the same destination—Davis-Monthan Air Force Base's Aerospace Maintenance and Regeneration Center in Tucson, Arizona, more familiarly known as "the boneyard." In transit, some of them appeared at airshows. "We painted them up real nice for the airshows and then they flew on to Davis-Monthan," says Madole. "We had the best-looking airplanes in the boneyard."

In addition to retiring the RF-4s, it was

Scott Madole's responsibility as Bergstrom's last active-duty wing commander to oversee the disposition of everything else on the base. All strictly military equipment had to be transferred to other Air Force bases requesting such items, which included flightsuits, helmets, oxygen equipment, cameras, tools to repair the RF-4s, tow tractors, and thousands of aircraft parts. There were also large stores of chemicals and digital-imaging computers that had been used to process the reconnaissance images captured by the RF-4s.

The devil is in the details, we're often told. That theme struck home the day someone discovered about $10,000 worth of chemical warfare protective gear in a dumpster. To prevent other ad hoc disposals, Madole set up a collection point for "anything that you don't know where it belongs." As for the thousands of records stored in the base's filing cabinets, all of them—except what was needed by the conversion agency to conduct the closing—had to be boxed, labeled, and shipped to a repository at Fort Worth.

Anything that wasn't strictly military equipment, such as desks, chairs, or trucks, was labeled "personal property" and could be transferred to the Local Reuse Authority based on demonstrated need. It was Dick Pautz's responsibility to process any equipment designated for reuse, help with the disposition of a variety of other items, and devise procedures for environmental cleanup.

Jim Zwernemann, who was now working for the conversion agency, handled much of the disposition of the personal property. Some of it went to other Air Force bases. "There were beautiful solid oak pews in the chapel," he says. "Those were loaded into a moving van and sent to Homestead Air Force Base." Most of the personal property, however, will be used by civilians. "There's a huge hangar filled with about $5.6 million worth of stuff that the new airport will take over, including desks and chairs as well as 50 vehicles—fire trucks, tractors, even a bulldozer," says Zwernemann. Hospital equipment has been distributed to several federal agencies.

"We can't throw anything away," says Zwernemann. "Whatever we can't dispose of in any other way goes to the Defense Reutilization and Marketing Office. I had to get rid of four crashed F-4s through that organization. They auctioned them off as scrap metal—48,000 pounds of it. The successful bidder came and picked it up with a tractor trailer."

The nearly 4,000 military personnel stationed at Bergstrom when it appeared on the closure list were reassigned to other Air Force bases in a steady stream that lasted for months. "We went to the moving companies in the area and asked them how many

Since hundreds of Bergstrom's residential units were situated on land earmarked for the new runway, they had to be moved elsewhere. E.C. Smith (above) took on the task of transporting them (below). "We roll along at 45 to 55 miles an hour," he says.

families they could move in a month," says Madole, "and that's what dictated how rapidly people were reassigned over the next year and a half."

Civilian employees, about 1,200 of them in the fall of 1991, would suddenly be out of work. Several had put in enough years and had sufficient ties to the Austin area that they chose to retire. A very small number were able to fill slots in the conversion agency for as long as it would be working at Bergstrom. Fortunately, the Air Force was able to find jobs for the remaining civilians in other parts of the federal system. Says Madole: "Of the people not ready for retirement, there were only about 12 for whom we couldn't find jobs or who chose not to relocate."

It goes without saying that these were traumatic times, and Madole did what he could to soften the blows. "I was very concerned with what people saw in their rear-view mirrors when they left," he says. "I wanted them to remember a good experience, so I tried extra hard to keep the base looking good till the very last."

For Madole, the hardest day was September 30, 1993, when he performed the closing ceremonies. "I retired 20 people with flagpole ceremonies in the morning, then [I] retired at lunch," he recalls. "In the afternoon we took the flag down, marched to the main gate, and turned over the [symbolic] keys to the mayor [of Austin] and city council. Then I got on a white horse and rode west into the sunset while F-16s did a flyby overhead. It seemed appropriate for Texas." With that gesture, Bergstrom Air Force Base ceased to exist operationally, transformed instantaneously into a hunk of land and buildings upon which someone else would build a future.

In 1942, the city of Austin agreed to buy land for an air base and the federal government agreed that if the base ever closed, ownership of the land would revert to the city. Though that agreement was never entirely formalized, both the Air Force and the Department of Justice agreed in 1991 that this reversionary right was valid for Bergstrom. In addition, the Air Force agreed to turn over all the improvements—buildings and infrastructure—at no cost to the city, a fairly standard

All that remain of base houses are the foundations (left). Many of the units—after being put on wheels (far right)—ended up in a new development (below).

Airport contractors tore down old structures (right, top) and recycled vast stretches of pavement by feeding chunks of it into a concrete crusher (right).

goodwill gesture that in most cases happens to be cost-effective for the military.

What to do with the unexpected beneficence? Like other cities with major base closings, Austin had many partisan groups with a slew of ideas: homeless shelters, low-income housing, a prison, a velodrome (a track for bicycle training and racing), a college campus, home for a regional law enforcement academy, a museum for combat jets, and an industrial complex.

The city of Austin, however, had been talking since 1975 about replacing Robert Mueller Municipal Airport, and had decided on a site east of Austin, at Manor. Three days before the city was to buy the land, Bergstrom appeared on the list of base closures, and the city decided to reconsider its options. "The first involved doing necessary changes to stay at Mueller for a projected cost of $1.4 billion," says John Almond, director of the New Airport Project Team. "The second was to build new at Manor for $900 million, and the third was to convert Bergstrom for $600 million."

The third estimate was based on the fact that, in addition to free land, Bergstrom's legacy included the 12,250-foot SAC-built runway and parallel taxiway. "That hunk of concrete was worth $80 million," says Holland Young, planning and environmental manager for the new airport. City planners thought the answer was obvious, and after a long public information campaign, so did the voters, who authorized a $400 million bond issue, to be supplemented with funding from the Federal Aviation Administration and other sources.

And so began the new-airport team's trek toward a 1999 opening. One of its first decisions was to figure out what to do with hundreds of Bergstrom living units—mostly duplexes—that were in the construction path of a new 9,000-foot runway (parallel to the original one), along with associated taxiways, ramps, and aprons, as well as a new control tower, terminal building, and parking garage.

Instead of taking on the considerable expense of demolishing the duplexes, the airport team gave some of them to Austin's Neighborhood Housing Services and other nonprofit groups and auctioned off the rest to for-profit developers and private individuals. All of the units would be moved.

Since most of the duplexes were too large to be moved in one piece, they were cut in half and handled as separate units. E.C. Smith, who has moved more than 200 of them, has the process down cold. He removes the brick siding, reinforces the walls inside and out, uses airbags to jack the building up on I-beams, and slips wheeled dollies underneath. Then it's off to wherever. "Once we get out of Bergstrom's main gate and onto the main highways," says Smith, "we roll along at 45 to 55 miles an hour."

When it came time to make Bergstrom environmentally sound, local engineers working for the conversion agency devised an environmental plan

secure in the knowledge that they had a "very clean" base with only $55 million worth of cleanup. By comparison, Carswell Air Force Base in Texas was projected to cost $90 million, and California's McClellan, the "dirtiest" of Air Force bases because of its storage of industrial solvents, PCBs, and hydrocarbons, was expected to require between $750 million and $1.2 billion worth of work. And yet a "clean" Bergstrom had 481 separate environmental sites, including underground fuel and oil tanks, sewer lines that had leaked noxious chemicals, fire-fighting practice areas where oil had been dumped and ignited, and accidental fuel spills, one of which had deposited a petroleum plume in the groundwater beneath the base. Bergstrom also harbored 58 acres of landfill.

Several sites were major undertakings. The petroleum in the groundwater was cleaned up with a method called air injection sparging and bioventing. The process requires drilling pipes into the ground, first to inject the groundwater with air to stimulate petroleum-eating bacteria, then to vent the resulting gases.

As for the landfills, they were so large that carting away their contents would have been too expensive. Instead, each site was sampled for pollutants, then covered with an impermeable membrane and topped with a layer of dirt and vegetation. Depending on your politics, the huge mounds look like grassy knolls or giant tumors. Either way, they must be monitored for leakage over the next 40 years.

The communities surrounding Bergstrom feared the economic disaster that frequently comes with the closing of a military base, but all of them managed to avoid it. The closing of Bergstrom had only minor economic impact on Austin, a city of 475,000. According to Mayor Bruce Todd, it has already recovered. "The closing of the base came at as good a time as bad news can come—during an economic recovery," he says. "In the mid-'80s, that would have been a disaster, but in the '90s we were able to absorb the impact in an efficient way."

If anything, the impact was a positive one, since the event provided a lowest-cost solution to Austin's pressing need for a new airport. "Air cargo is growing at 20 percent to 30 percent per year," says Todd, "and the growth in passenger traffic is second highest in the country. Soon we would have been turning away cargo traffic with serious

The RF-4 mounted near Baty Elementary School in Del Valle symbolizes the respect the town had for the nearby base.

A few Del Valle businesses dependent on military customers were forced to close, but Dairy Queen owner Mary Thomas (below) was not affected. "We serve mostly local people," she says.

effects for Austin's high-tech manufacturing community."

The picture is somewhat different for Del Valle, a little town of about 1,400 residents that sits just outside Bergstrom's main gate. Some businesses dependent on military customers closed, including a laundry that did a lot of alterations on uniforms. One apartment complex with a high percentage of military renters took a hard hit, but has managed to restore itself. A Dairy Queen owned by Bobby and Mary Thomas was barely affected. Says Mary Thomas: "We saw a difference in the amount of traffic, but the difference in money didn't amount to much."

It's the Del Valle School District that has been most seriously affected. Bergstrom children went to Del Valle's schools, and superintendent Edward Neal says that the relationship with the military was always very close. "In the early days, the school district bought water from the base, which also provided essential services like fire protection and ambulances," he says. "And since there were few county services, the base provided crossing guards and buses." Del Valle residents were also allowed to use Bergstrom's golf course, theater, and meeting rooms.

As Del Valle grew larger and more independent, its use of some base services tapered off, but Bergstrom remained committed to the community and provided the school system with some unique services. Neal recalls that on one occasion Bergstrom's base commander authorized the use of helicopters to hover over the high school football field to dry it off before a game. The most visible symbol of the connection between base and town is the

"mummified" RF-4 reconnaissance jet that was set up as a monument across from Baty Elementary School.

When Bergstrom closed, Del Valle school enrollment dropped from about 5,600 students to 4,200—not a devastating loss since the area is growing. Already, the student population has bounced back to nearly 5,000. "But the greatest loss was in military people who served on school committees and as mentors for the children," says Richard Vasquez, who grew up as a military brat in Bergstrom housing and attended Del Valle schools. "Bergstrom people were highly committed to education."

The biggest shocker was yet to come when it became clear that the flight path for the airport's new runway would pass directly over all four Del Valle schools. Superintendent Neal describes an impossible situation: "The noise would have disrupted classes, but there were also health and safety concerns with the possibility of crashes and especially noxious exhaust fumes."

Del Valle and the city of Austin agreed that the best solution was to move the schools, though at the moment it's not clear whether the new schools will be finished in time for the opening of the airport slated for the spring of 1999. The high school, with its football field and track, almost certainly will not be ready. There's talk among the townspeople of forcing the new airport to abate operations on the second runway until all the schools are moved, but neither Austin nor the FAA would react cheerfully to that measure.

Bergstrom's departure has spawned another possible source of contentiousness: The new runway's flight path will be just at the edge of Del Valle's Richland Estates subdivision. About a dozen homes will be sound-insulated, but most of the residents will have to fend for themselves. Most of the Richland Estates residents are retired military, and adding to their sense of violation is their loss of convenient access to privileges they're entitled to: medical care and the use of low-cost military facilities like the commissary and the base exchange store.

Richard Vasquez and his father Alfredo both live in Richland Estates, and they're upset. "The city tends to say: 'Well there was plenty of noise from the B-52s and RF-4s, and you got used to that,' " he says. "It's true, we did get used to it even though the flight path for the B-52s was very close to my family's home. I could see the pilots in the cockpit as they were landing." But he points out that commercial airline traffic will be much more frequent. "Besides," says Vasquez, "when you're in the Air Force you learn to live with the noise because it's vital to your existence. But we don't have any stake in Austin's airport."

Turning an air base into an airport was bound to cause some discord, but what better use could possibly be made of Bergstrom? The spirit of the place may in some way be preserved. One military couple will forever treasure the single brick that Scott Madole saved for them from the base chapel where they were married. And when Irene Gallet finally visits the finished airport, she'll likely see, beneath all the new concrete and steel, the image of the building where she worked, and find in the roar of passenger jets a familiar memory of B-52s winging their way back from a long mission.

Signs of Bergstrom's proud past are still visible amid the general disrepair, though not for long: Airport contractors have marked the base operations building for demolition.

by Henry S.F. Cooper Jr.

Illustrations by Paul DiMare

SOME ASSEMBLY REQUIRED

Space stations don't just build themselves. It takes 75 spacewalks and a chest full of tools.

Although robot arms will place solar arrays, truss sections, and other large pieces of the station in position, most of the final hookup will be done by human hands.

Next year, if the schedule holds, the cornerstone of the International Space Station will at long last be laid in orbit. The first piece, as it happens, is Russian: The "functional energy block" for attitude control and propulsion, which goes by the acronym FGB, will be launched from the Baikonur cosmodrome in Kazakhstan on a Proton rocket. Shortly after that, the space shuttle *Endeavour* will blast off from the Kennedy Space Center in Florida carrying the first U.S. component, Node 1, which attaches to the FGB and has six docking ports for other modules and vehicles.

The station is scheduled to be completed in June 2002. By that time, U.S. astronauts will have spent 900 man-hours, on 75 spacewalks, just building it. NASA will conduct more extravehicular activities (EVAs) in the years 1999 and 2000 alone than it did in its entire prior history. Add to that as many as 200 hours of spacewalking by U.S. astronauts for maintenance, even while the station is still under construction, and one begins to appreciate the magnitude of the job ahead.

Some experts feel that with respect to EVA experience, we are already behind the curve. One such worrier is Story Musgrave, who made the first shuttle spacewalk in 1983 and was in charge of repairing the Hubble Space Telescope in orbit 10 years later. Musgrave believes that a key to EVA success is to start astronauts training as early as possible with real tools and accurate mockups of the equipment they will handle in orbit. "What you need to do, with a huge up-front investment, is to jump on the details early in order to head off any surprises and to avoid last-minute changes," he says.

The way things went on Musgrave's last shuttle flight in December "convinced me we weren't there yet," he says. Two other astronauts were supposed to conduct a pair of EVAs to practice techniques and test equipment for assembling the station, but a broken handle on the airlock hatch prevented them from even going outside. Now the two spacewalks canceled from mission STS-80 will be combined into one, on mission 87 this October.

Recognizing the importance of training astronauts to build the space station, NASA set up a new EVA project office last year. Donald McMonagle, the astronaut who heads it, admits there is a lot of truth in Musgrave's comments. His office is trying to bridge the experience gap in a number of ways, including more training with tools and techniques on the ground, even before astronauts venture into the neutral-buoyancy water tank used to simulate zero-G, where time is at a premium.

Because the best EVA experience is in space, though, some of the training

The drudge work in building the station will be connecting its hundreds of electrical cables and fuel lines.

necessarily will be on the job, once assembly starts. Musgrave is not satisfied with that solution. He likens a well-crafted EVA to a well-rehearsed ballet. "What ballerina goes into opening night and says, 'I'll get to learn the choreography as I go along?' You should be up to scratch before you start." Musgrave, who leaves NASA this summer after 30 years and six shuttle flights, has three words of advice for the space agency: practice, practice, practice.

The man in charge of hooking up Node 1 to the Russian FGB on mission 88 is Jerry Ross, a short, intense man who heads the astronaut office's EVA and Robotics Branch. Node 1, like all the station modules, will be set in place by the orbiter, which will shove it into a port on the FGB, very much the way the shuttle docks to the Russian Mir station (see "United We Orbit," Dec. 1996/Jan. 1997). Then Ross and his partner, James Newman, will go on three EVAs, using the shuttle airlock for their exit (the U.S. airlock for the station won't arrive until later).

While outside, Ross and Newman will install some handrails, foot restraints, a slide wire for moving along the station's exterior, and other equipment. But the main thing they will do is hook up electrical cables—perhaps the biggest overall chore in assembling the space station. This is painstaking, meticulous work. The cables can be stiff with cold and the edges sharp. The connectors are a little like the ones with pins that plug into the back of a computer, but bigger. The astronauts have to make sure no debris gets between the pins, and to be careful not to bend them when they push in the connectors. "It's just a very precise, very demanding task, and it takes time," Ross says.

Another job facing the orbiting construction crews is assembling the station's 310-foot girder-like truss, which will begin only after most of the modules are in place. Each of seven 45-foot segments will be brought up by the shuttle, whose manipulator arm will place them within about a foot of their proper position. Much of the final hookup will be done by astronauts. Later, another manipulator arm similar to the shuttle's will be fitted on top of the truss, where it will ride on tracks and deliver equipment—instruments, radiators, and pieces of the solar arrays—from the shuttle to almost any part of the station. (The most dangerous EVA an astronaut may ever have to perform—indeed, the most dangerous eventuality of any sort on the space station—is jettisoning a damaged solar array. The array's odd shape and center of gravity would cause it to tumble unpredictably, and its sharp edges could easily slice into a spacesuit.)

NASA wants to do as much of the construction work as possible with the robotic arm, but the arm has a limited ability to manipulate objects. Engineers are working on a virtual reality system that would let astronauts inside the station control a two-handed robot outside. The robot has "fingers" and a pair of cameras for eyes; by putting on a helmet, the astronaut would see what the robot sees, and could manipulate the robot's fingers by wearing special gloves. It will be a while, though, before the virtual reality system can replace an astronaut on EVA. Nearer at hand is a small free-flying robot the size of a basketball, with a camera that can inspect out-of-the-way areas of the space station for damage. One version of the "Aircam" might be able to fly a tool out to a forgetful astronaut. A little further off is a helper robot that astronauts could take along with them to hold tools and perhaps do basic work—their own primitive R2D2.

But while the engineers dream, spacewalking astronauts will have to do the grunt work, all of which involves connecting hundreds of electrical or fluid lines. Asked what he thinks is the major hurdle in building the station, McMonagle says, "Being able to get all the connectors connected."

"There is not one hurdle you look at and say, 'Once we're over that hump we've got it?' " I ask.

"No," he says. "We have a whole line of little humps. The connectors are the major category of little humps."

The Russians, who plan to attach several modules of their own to the station, will not have to worry so much about these particular humps. Most of their connectors are internal, many hooking up automatically when the modules are attached. McMonagle says the reason NASA didn't design its modules the same way was that external connections were more cost-effective—a major factor in space station design. It also avoids the problem of having a welter of hoses and cables inside the cabin, as Mir does.

Intensive preparation for building NASA's space station began around 1989 (in those days it was called Freedom), when a number of managers and astronauts, including Jerry Ross, felt that the agency needed more EVA practice in orbit. Many astronauts had retired after the *Challenger* accident, and Ross and Musgrave were among the few remaining who had spacewalk experience. In 1985, Ross and crewmate Sherwood Spring had built from scratch two varieties of giant truss segments, called EASE and ACCESS. Though they accomplished the task handily, NASA later decided not to build trusses TinkerToy fashion, but rather to assemble ready-made sections.

Ross and other astronauts had found that moving about in space while remaining tethered to the spacecraft or transporting bulky equipment (which often is attached to an astronaut by a tether) was tricky business. It was very easy to "put in rates" or get "off-axis"—astronaut talk for getting off-kilter and wobbly so that spacewalkers and their loads flop about. The more massive the

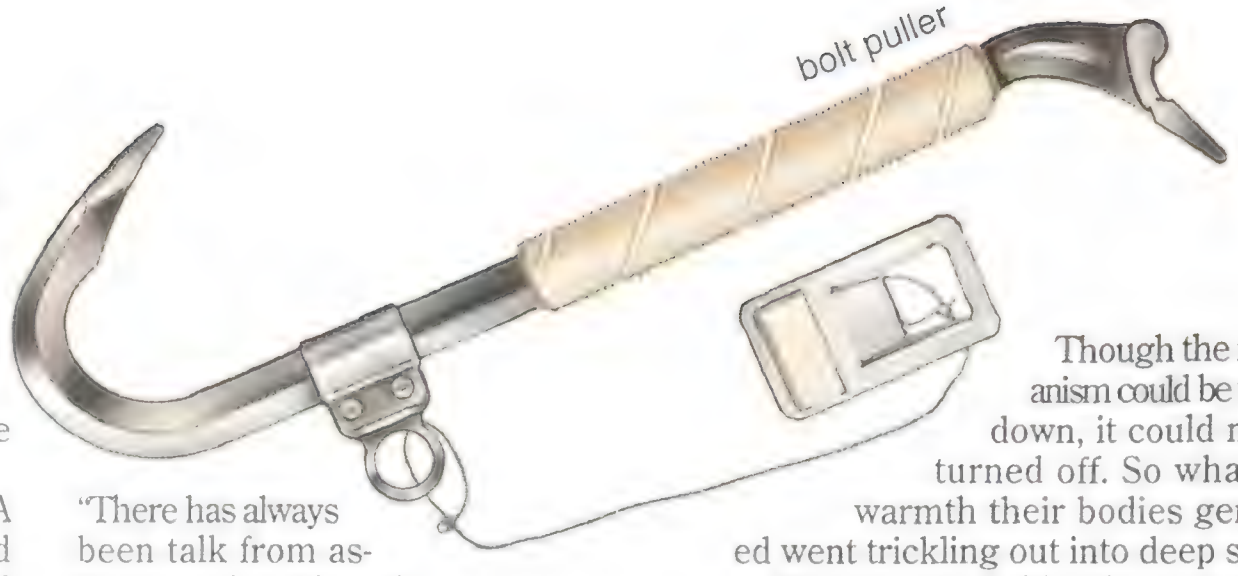
load, the worse the problem.

In 1990, Ross sketched out an idea for a cart, called the Crew Equipment Translation Aid or CETA, which rides on tracks running along the truss. A year later, on mission 37, he got to test prototypes in orbit; two versions, including one that worked like a railroad cart, were later discarded.

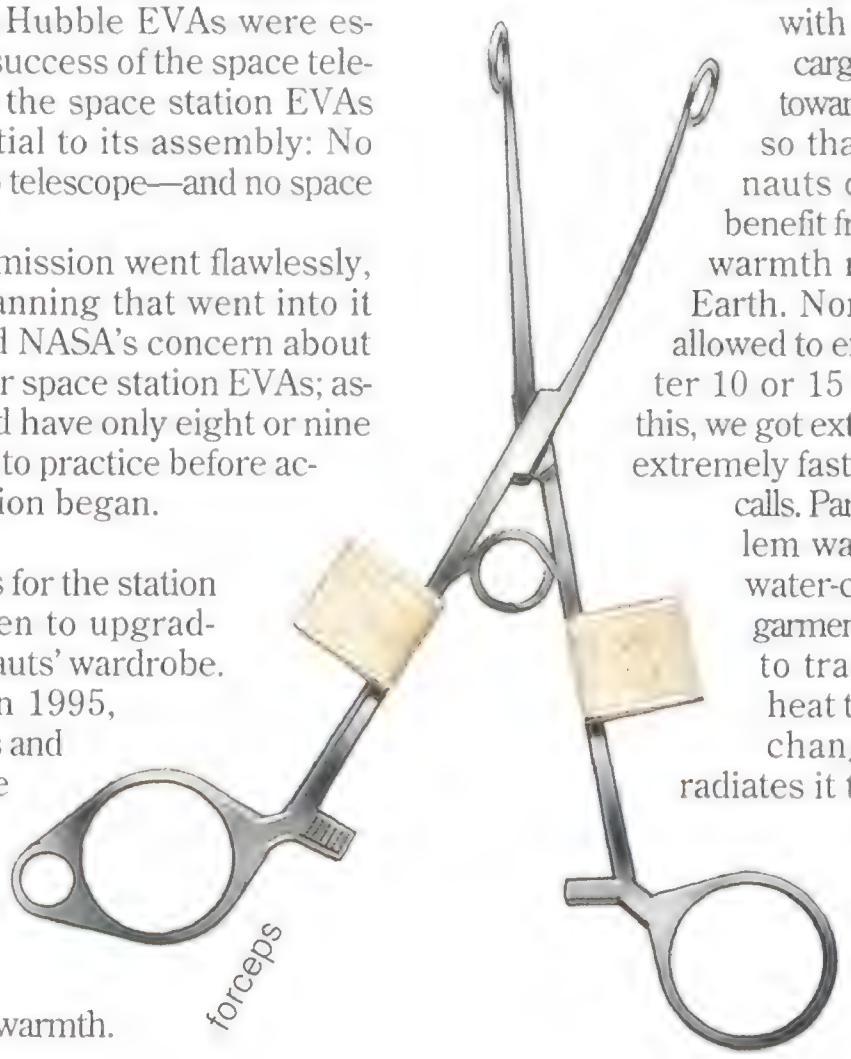
Little more than a dolly, the CETA has an upright post that holds tools and gives astronauts (who will be attached to the cart by foot restraints) something to hang on to. It has no wheels—just rollers that keep it on its T-shape rails. Using their hands, spacewalkers will pull themselves and their equipment along to any spot on the truss, then use the cart as a workstation. One of its accessories is a small hand-operated crane whose boom can telescope to 18 feet for hoisting large and massive components, such as solar panels or instrument boxes, to the right spot.

With the CETA checked out, the next major step in preparing for the space station was the December 1993 Hubble repair, during which two pairs of astronauts corrected the telescope's faulty vision in orbit. Up until then, spacewalks, even the ones on the moon, were secondary to other goals—though important, they were not central to the mission. The Hubble EVAs were essential to the success of the space telescope, just as the space station EVAs will be essential to its assembly: No spacewalks, no telescope—and no space station.

The repair mission went flawlessly, but all the planning that went into it only increased NASA's concern about being ready for space station EVAs; astronauts would have only eight or nine more chances to practice before actual construction began.



Preparations for the station extend even to upgrading the astronauts' wardrobe. On STS-63, in 1995, Bernard Harris and Michael Foale tested NASA's shuttle spacesuits, which have been flown since 1983, for warmth.



"There has always been talk from astronauts that when the sun is covered by the Earth, it gets awfully cold. But nobody has ever documented how cold it was," says Harris, a trim man with a brisk manner. At the same time, some NASA engineers were saying, "Sure it gets a little cool, but it's not a problem." It was important to settle the issue. It will be colder outside the space station than outside the shuttle, since the station's orbit is inclined 51.6 degrees to the equator, compared to 28 degrees for the shuttle, and high latitudes in space (like high latitudes on the ground) are dark for long periods during certain times of year. Temperatures in orbit can drop to 200 degrees below zero Fahrenheit on the dark side of Earth.

To test the suits under the coldest conditions, Harris and Foale went outside in darkness, with *Discovery*'s cargo bay turned toward deep space so that the astronauts didn't even benefit from the wan warmth radiated by Earth. Nor were they allowed to exercise. "After 10 or 15 minutes of this, we got extremely cold extremely fast," Harris recalls. Part of the problem was that their water-cooled inner garment is designed to transfer body heat to a heat exchanger, which radiates it to space (in shuttle orbits, astronauts can overheat while working). Though the mechanism could be turned down, it could not be turned off. So whatever warmth their bodies generated went trickling out into deep space.

"First you get cold at the extremities and then your core temperature begins to drop," explains Harris. "We knew it was going to get cold, but nobody knew how cold it was going to get, or how fast." The astronauts alerted their commander, who pointed them toward Earth, and they began moving around to warm themselves until the sun came up. "That was 45 minutes later—an awfully long 45 minutes," says Harris.

Even after they started exercising, the temperature inside their gloves—the suit was equipped with heat sensors—dropped to 20 degrees. (Harris' feet got cold too, but they are unusually big, leaving less room for air in the boot; Foale's feet, which are small, did not freeze.)

Another test in the cold—handling the 3,000-pound Spartan satellite—had to be called off. "The handling tool was made of metal and it was so cold that when you grabbed it, your hand froze," Harris remembers. When the sun came up, though, the astronauts warmed up very fast—the reverse of what had happened to them after sunset. They were able to handle the Spartan in the daytime, gathering more data on the difficulty of moving heavy objects.

As a result of the test, the engineers snapped to. For the next EVA, on mission 69 in September 1995, they provided heating elements in the gloves and added a mechanism for bypassing the constantly cooling radiators. Now heat can recirculate back to warm the person inside the suit, not the universe. The mission 69 astronauts, James Voss and Michael Gernhardt, found their suits snug and toasty. They also tried out new helmet lights, which they liked. Unlike a miner's single lamp, these are a pair of small lights facing forward on either side of the helmet. Like headlights with high and low beams, the new variety can be switched from a

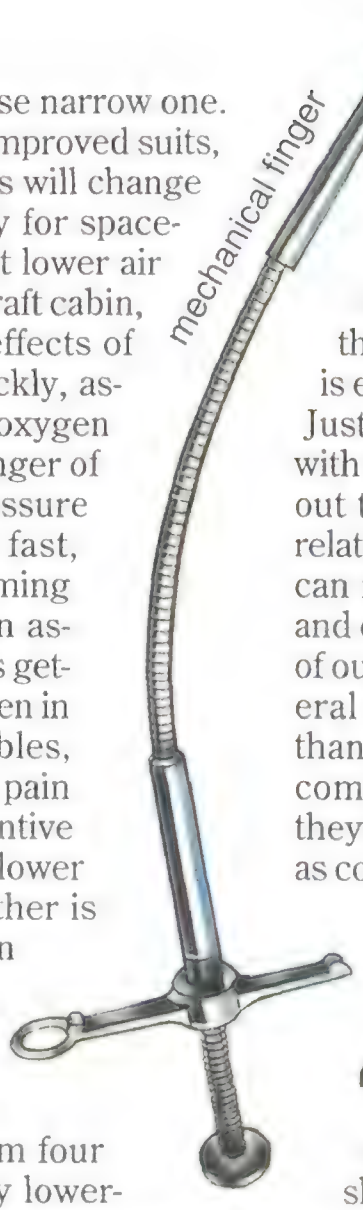
broad beam to an intense narrow one.

Along with wearing improved suits, space station astronauts will change the way they get ready for spacewalks. Spacesuits are at lower air pressure than a spacecraft cabin, so to avoid the nasty effects of depressurizing too quickly, astronauts breathe pure oxygen before an EVA. The danger of going from higher pressure to lower pressure too fast, whether for a diver coming up from the deep or an astronaut going on EVA, is getting the "bends": Nitrogen in the blood creates bubbles, which can cause great pain in the joints. One preventive measure is to go to the lower pressure slowly; the other is to breathe pure oxygen ahead of time, which drives the nitrogen out of the blood.

NASA has cut this pre-breathing time from four hours to 40 minutes by lowering the pressure throughout the shuttle the night before an EVA from its normal 14.7 pounds per square inch (the pressure at sea level) to 10.2 psi. Since this won't be an option on the station, EVA astronauts will camp out in the airlock at lower pressure the night before a spacewalk; they will be allowed out only for breakfast and to use the bathroom.

NASA flight surgeons now think that weightlessness inhibits the formation of nitrogen bubbles, so it may be that astronauts can reduce the pre-breathing even further. It may also be that exercising during depressurization and pre-breathing, which many astronauts have started to do, helps. If a spacewalker ever did get the bends, he or she would return to the airlock and be given aspirin and oxygen. Because the cure for bends is the opposite of its cause, the suit would be pressurized to 8 psi higher than the airlock pressure of 14.7 psi.

Russian spacesuits have more sections made of hard shell than do American suits, and they operate at higher pressure; as a result, cosmonauts need to pre-breathe for only 30 minutes. The Russian suits also are easier to get into:



A cosmonaut simply opens a door at the back of the shell and jumps in, while an American astronaut struggles to put on pressurized pants before crawling into his suit's upper torso. But the U.S. suit, with its lower pressure, is easier to bend at the arms and legs. Just as our astronauts envy the speed with which cosmonauts suit up and get out the hatch, the Russians envy the relative ease with which our astronauts can move around in their spacesuits, and especially the manipulative ability of our gloves. American EVAs, by general consensus, are less exhausting than Russian ones. When astronauts come back inside from a spacewalk they report feeling exhilarated, whereas cosmonauts are often worn out. Russian EVAs are normally kept to five hours, whereas ours normally exceed six hours.

"The biggest worry every astronaut has is whether he or she is going to drift away from the ship," says Bernard Harris. "When you are dealing with different masses traveling at speed, you can float away from a ship fairly quickly and begin to separate. There is a point at which the ship cannot come back and get you; it will have to wait until the next revolution, if you are still there. Ninety minutes later, though, you might be in a different orbit."

No American astronaut has ever come untethered, though this happened briefly to a Russian, Yuri Romanenko, during an unplanned walk outside the Salyut space station in 1977. His commander, Georgi Grechko, later recalled, "The loose end [of the tether] was floating by. I grabbed it just in time. I said, 'Yuri, where are you going?' "

Musgrave points to the episode as an example of what can happen when astronauts or cosmonauts try something in space they have not practiced sufficiently on the ground. Romanenko's EVA was entirely impromptu—he wasn't even scheduled to go outside, but he'd begged Grechko for a few minutes of fun after the commander finished his own planned spacewalk.

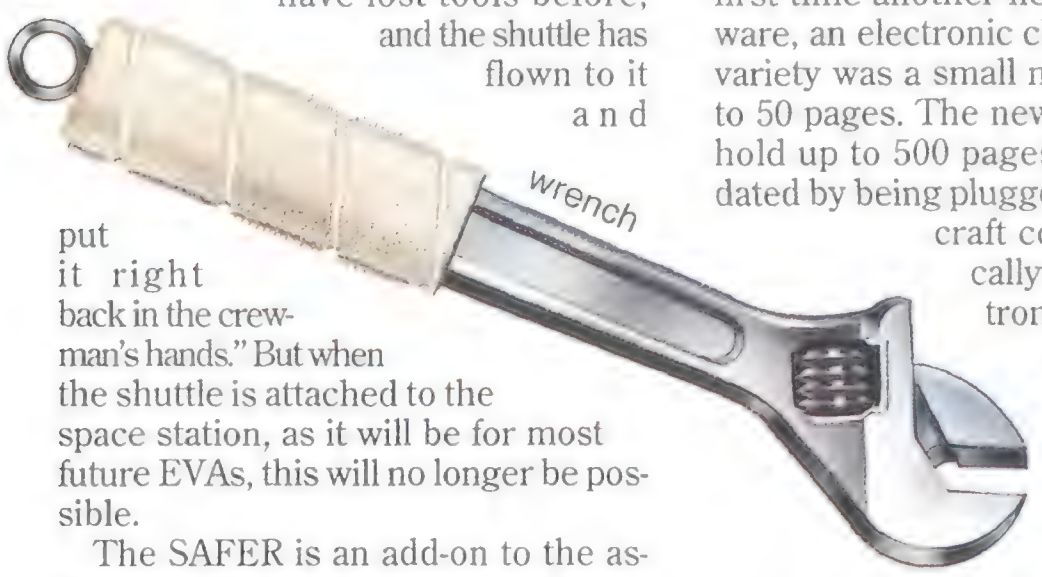
By and large the Russians rehearse less than the Americans and seem to get into more trouble. In June 1991, toward the end of an exhausting EVA aboard Mir, Anatoly Artsebarsky's face plate got fogged and he couldn't see; his partner, Sergei Krikalev, had to lead him back to the hatch. "I was guiding him—talking to him, telling where to go, where to grab," Krikalev recalled later. "It was really dangerous." To avoid this sort of problem, American astronauts always coat the inside of their face plates with an anti-fogging compound; the downside is that if they get their faces too close, it will sting their eyes badly.

No astronaut has been in a life-threatening situation on a shuttle EVA. About the worst thing that has happened, according to Musgrave, is getting tangled in a tether, and that occurs quite frequently. Michael Foale, in fact, got himself badly tangled toward the end of his mission 63 EVA, and Harris had to talk him out of the mess while being careful not to get wrapped up himself.

To be on the safe side, NASA has developed a sort of space parachute called the SAFER, which stands for Simplified Aid For EVA Rescue—a tailor-made

acronym if there ever was one. So far a backup to conventional tethers hasn't been necessary; the current plan is for the orbiter to retrieve any wayward astronauts with the robot manipulator arm, or scoop them up in the cargo bay the way you might catch a fly in a cupped hand.

"The shuttle is a magnificent flying machine," says Musgrave. "We have lost tools before, and the shuttle has flown to it and put it right back in the crewman's hands." But when the shuttle is attached to the space station, as it will be for most future EVAs, this will no longer be possible.



The SAFER is an add-on to the astronaut's life-support-system backpack. It is descended from the Manned Maneuvering Unit (MMU) worn by shuttle astronauts in the 1980s but is smaller, simpler, and cheaper. The MMU was meant for transportation—it was a sort of space bicycle. The SAFER has only one function: to back up the tether. The MMU weighed 500 pounds, the SAFER, 80; the MMU could go 66 feet a second, while the SAFER clocks only 10 feet per second; the MMU's batteries cost $100,000, compared to $50 for the SAFER's off-the-shelf alkaline ones. The MMU had all sorts of redundancy, while the SAFER is what space engineers call "single string," like a parachute with just one rip cord. This is fine with the astronauts; they see the SAFER itself as a redundancy.

On mission 64, conducted in September 1994, Mark Lee and Carl Meade took turns testing the device in space. One astronaut, standing secured to the manipulator arm, would rotate his SAFER-wearing crewmate in roll, pitch, and yaw, then let him go so that he spun like a top. When the arm pulled back, the astronaut was left spinning pretty much in the predicament he would be in if he became unstuck from the space station. Each time, the spinning astronaut pressed the automatic attitude-hold button on the SAFER's control panel (which appears in front of him at the touch of a lever). The spinning rate was about 30 degrees a second, and the SAFER's jets—small ones handed down from the Strategic Defense Initiative program—would stop him cold in less than 80 degrees. "That button worked really well," Lee says. "It gave me a great sense of relief."

Lee and Meade also tried out for the first time another new piece of hardware, an electronic checklist. The old variety was a small notebook with up to 50 pages. The new one, which can hold up to 500 pages and can be updated by being plugged into the spacecraft computer, is basically a 2.5-pound electronic organizer with a three- by four-inch screen. For control, the screen is divided into six pressure-sensitive areas the size of a spacesuit finger. By pressing different areas of the screen, astronauts can call up an index and different sets of choices, and more choices within each of those choices in a sort of electronic tree, until they get the data they want. By and large the astronauts like it, though it still has bugs; interfacing a computer and a spacesuit glove is a smudgy business, and sometimes the astronauts get lost as they feel their way with hamfists along the branches of the information tree.

On mission 72, conducted in January 1996, three astronauts, Daniel Barry, Leroy Chiao, and Winston Scott, evaluated about 20 pieces of equipment and tools that will be used to assemble the space station. Among them were a Portable Work Platform for an astronaut riding around on the end of the manipulator arm. The PWP includes a foot restraint that can tilt in any direction, a post for holding tools, and another post to hold equipment to be installed on, or removed from, the station.

hydrazine brush

Most of the other tools were designed for connecting and disconnecting electrical cables, which Barry spent a lot of time doing. This meticulous work can be very hard on the fingers, since even American gloves are too stiff for spacewalkers to hold objects in their palm. "It's remarkable—it's these tiny muscles in your fingers that make the difference," Barry says. He is a slender, agile astronaut with an obvious enthusiasm for EVAs. For a year before the mission, he drove to work in the mornings with his left hand on the wheel and his right squeezing a racquetball between his thumb and first two fingers. On the way home, he reversed the procedure. "That really did the trick!" he says. "Now I can crush beer cans between my thumb and fingers."

Barry also evaluated some new rigid tethers for anchoring himself to the spacecraft. The old leash-like tethers don't keep a floating astronaut steady—spacewalkers end up having to use one hand to hold themselves in position. The alternative is a portable foot restraint, but these are more trouble than they're worth, says Barry. "You have to go and get the foot restraint from wherever it is, bring it with you, mount it, clamp it in properly, adjust it so that it is pointed in the right direction, get up, clamp your feet into it, do your task, get your feet out, unplug it, reconfigure the site, then take it back to wherever it has to go and put it away again."

Barry gave one new device—the multi-use tether, or MUT—very high marks. Unlike the flexible tethers on reels, the MUT lets astronauts anchor themselves firmly in one place, a little like one of those walking sticks with a seat on top. It also offers the advantage of being able to attach either to round U.S. handrails or square Russian ones. The mechanism is a stack of balls with a cable running through them; the balls are loose until a handle is clamped down, tightening them together, in the manner of certain children's toys. Though the MUT didn't hold him in position as well

as the foot restraints, it held him tightly enough, and saved time—a tradeoff Barry recommended when he got back.

Two months later, on mission 76, Linda Godwin and Rich Clifford went on a couple of EVAs while the orbiter was attached to Mir. Though they did not go on the Russian station, they did go on the U.S.-built docking adapter that linked the two vehicles. Their main task was to carry four large flat boxes of experiments called the Mir Environmental Effects Payload (MEEP) from the shuttle's cargo bay and attach them to the outside of the adapter. These contained a variety of materials that would be tested for exposure to the environment outside Mir. Godwin gave high marks to the new rigid tethers, including ones used to anchor large pieces of equipment to themselves so they don't flop about. The only flopping about occurred later, after one of the MEEP's packages was attached, when its lid swung around and almost hit her on the helmet.

Godwin was sorry she couldn't go on Mir, but Russians and Americans do not want each other's astronauts clambering around on their space stations. Fortunately, both Russian and American modules plug into Node 1, where the airlock is, so astronauts and cosmonauts need not cross international boundaries when they go on an EVA. One reason for this chauvinism is pride of possession—the way new Cadillac owners might not want others climbing around on the hood. Another reason is that the exteriors of the shuttle and Mir, and of the Russian and American space station modules, are sufficiently different that each requires special training to navigate. Last April 29, NASA astronaut Jerry Linenger became the first astronaut of either country to conduct an EVA from the other nation's spacecraft. He trained for it in Moscow, had a Russian partner, wore a Russian spacesuit, and used Russian equipment.

Because there may be emergencies when an American or a Russian might have to go on the other country's module, the two countries are developing some joint hardware—a common foot restraint and common tethers. (Otherwise, Russians and Americans have different equipment, even down to the kinds of nuts and bolts they use.) On her flight, Godwin found that the jointly developed foot restraint worked very well, and that the tether—basically a Russian design—was easier to operate than the American version, because it could be opened by using a single hand action instead of pressing two buttons.

She also practiced moving around the way the Russians do. When cosmonauts want to go somewhere, they unhook one of their two waist tethers and hold on with one hand while they move the tether further on. Then they repeat the process with the other tether, always holding on with one hand

Hardware for station assembly is still evolving. This early design for the CETA cart looks like a railroad pushcart, but the final version will be pulled along its tracks by hand.

and one tether, as though they were rock climbing. Godwin preferred the way we do it: attaching the tethers to a slide wire and shoving along. The trouble is that unlike the shuttle cargo bay, the Mir is too cluttered with equipment and handrails to permit these wires. The Russians don't use foot restraints very much; they find they can anchor themselves very well by tucking their toes under the abundant rails.

Russian spacewalks differ from American ones in other respects. "When we do our EVAs," says Barry, "for the most part we know exactly what we are going to do, and we have it planned down to the minute." The Russians plan their spacewalks in much less detail; they hand the cosmonauts a list of things that need to be done and give them the flexibility to work through the list as best they can. McMonagle thinks that during the construction phase of the station we will still need detailed, American-style planning for EVAs. But after that, when astronauts and cosmonauts are doing maintenance chores of the type that cosmonauts now perform routinely outside Mir, the more flexible way is best. "I would expect your crewman ten years from now to have a standard set of tools, like your plumber," he says. "And if he didn't get the entire list [of repairs] done in one visit, he would pack up his bag and come back again another day."

hammer

Last February, Mark Lee and three other astronauts repaired and upgraded the Hubble telescope for the second time in orbit—still the paragon of EVA work. After his return Lee said he still agreed with Musgrave that more preparation was needed, but that the repair mission gave him confidence that NASA is "real close to being ready" to build the station. One new device he and his crewmates tested is a power tool for tightening and loosening bolts. The torque needed for each bolt is measured and recorded in the electronic wrist checklist; that way, the tool can be set to apply the precise force on the next mission. (The precision is required because the bolts are made only as strong as they need to be and could break if too much force is applied.)

Lee says he prefers the kinds of wing tabs used on some of the Hubble bolts, because he could undo them by hand instead of having to use tools. But not every bolt can use them. And the new power tool worked beautifully, he reports. Some of the telescope's bolts, though, had become frozen in space (no one quite knew why; it wasn't rust), and Lee worried that there could be shearing problems on future missions.

The electronic wrist checklist worked better than it had on his first mission, and the ability to retrieve information by pressing the screen was much improved. But the system tended to act up in cold temperatures, and felt a bit bulky on the astronauts' wrists. They brought their old cardboard checklists as backups. "I hope the engineers get all the bugs out, because it is a very valuable tool," Lee says.

He also was delighted with the new helmet lights with broad and narrow beams, which lifted any restrictions on working at night. The lights had been especially useful when he had gone inside the Hubble, which he found glistening and pristine, the way it was at launch—unlike the outside, which despite its gleaming appearance in photographs has been pitted by micrometeorites and discolored, with some of the insulation cracking.

The final practice sessions before space station construction begins will be on the orbiting Mir-shuttle complex. Russian and American astronauts will venture out together, following up on Jerry Linenger's inaugural four-hour EVA with Vasily Tsibliev to do maintenance work outside Mir. In September, on mission 86, Scott Parazynski and Vladimir Titov, a cosmonaut who has already flown once aboard the shuttle, will float from the cargo bay onto the docking adapter to retrieve the MEEP packages left by Godwin and Clifford last year.

The last preparatory EVA, unless more are added to the schedule, comes on mission 87 a month later, when Winston Scott (last seen practicing connections with Barry on STS-72) and Takao Doi (who will become the first Japanese to walk in space) will combine the two EVAs lost on mission 80 last year, salvaging about 70 percent of the work. This will include testing the CETA cart's new built-in crane, which the astronauts will use to simulate the changeout of 350-pound space station batteries. They also will decide between two ball-and-cable MUT tethers. Eventually there will be a runoff between the winning MUT and another kind of folding semi-rigid tether, but that will have to wait until the astronauts are at work on the station itself.

Plans for the space station aside, the greatest experience on an EVA is, and always has been, simply being on your own outside the spacecraft, a satellite yourself. "What a gorgeous view!" Harris says. "Here I had been looking at the Earth from inside the orbiter from the porthole. But now I've got a whole face full of Earth!" Mark Lee says describing the experience is like trying to explain what spring is like from inside a house—you have to go outside.

Every astronaut I talked to echoed that sentiment. "The sense of expansiveness...is greater outdoors," Musgrave says. "There you are 130 miles high, going 18,000 miles an hour. It's like riding on a motorcycle or a horse as opposed to being inside a car."

I asked Musgrave to run down the other senses.

"Feeling?" he began. "The suit is floating, and you are floating inside the suit, and there is nothing on the ground that is going to simulate that.

"Smell?" he went on. "The smell inside the spacesuit is very clean...not at all like being in a gymnasium. You should not sweat in a spacesuit; you should cool yourself down because water is a resource you want to conserve.

"Hearing? There is a nice steady hum from the fan in the environmental con-

Describing the experience of an EVA, says veteran spacewalker Mark Lee, is "like trying to explain what spring is like from inside a house—you have to go outside."

trol system, which whirs at 19,000 rpm. You hear conversations in your headset. Otherwise, there is nothing—unless you are touching the shuttle with your suit. Once I heard one of the [shuttle's] reaction-control jets go off. '*That's funny*,' I told myself. '*You can't hear in a vacuum*.' " It turned out that a metal piece of Musgrave's suit was in contact with the spacecraft. "Anything that will make your suit vibrate, you will hear," he says.

Perhaps the most unabashedly exuberant of the astronauts I met was Barry, whose face lit up at the memory of his EVA. "The colors of the Earth are spectacular," he says. "They are the colors of gemstones, from shades of emerald greens to ruby reds.

"When you look at the Earth or the moon, the three-dimensional aspect really pops out. The mountains jump up and the valleys really are deep. The contrasts are enhanced: the darkness of the oceans against the lightness of the clouds, which are so bright that it hurts your eyes to look at them.

"And the moon looks like a ball instead of a pie. Whether it's the clarity of the light and the sharpness of the shadows—because there is no atmosphere—I don't know. But it really looks like you are flying between the Earth, which you appreciate the curvature of, and the moon, which no longer is a flat plate.

"At one point I was up above the shuttle standing on the robot arm. That put me about 40 feet above the spacecraft, and I could look down and see the entire orbiter below me, friends waving out the window, the Earth stretched below, the moon above, the stars all around me—and that's where I just stopped for one minute and drank it all in. I tried to pinch myself, but you can't do that in a spacesuit. The EVA officially lasted six hours and nine minutes, but I say it was six hours and eight minutes for NASA and one minute for Dan!" ✈

VIETNAM MEMOIR

Tullo and the GIANT

USAF MUSEUM, WRIGHT-PATTERSON AIR FORCE BASE

For pilots shot down over North Vietnam, the way home was jolly and green.

by Robert A. Hanson

Frank Tullo has never forgotten his first day as a captain. He was 25 years old and flying from Korat Royal Thai Air Base, one of two F-105 bases in Thailand. News of his promotion had come through late the evening before, and he had sewn a pair of shiny new captain's bars on his flightsuit. He was wearing those bars when North Vietnamese gunners on the outskirts of Hanoi shot him down.

I heard Tullo's story a few years ago when he was an airline captain and I was negotiating the sale of radios to his airline. I flew 122 missions in F-4E Phantom IIs, also out of Korat but at a later time in the war. Many of my friends had been shot down over there, and a lot were never heard from again. Most fighter crews were not optimistic about their chances for rescue.

Pilots of the F-105 Thunderchief, or "Thud," in particular, suffered a high loss rate. There was a standing joke among the often chain-smoking Thud crews that the definition of an optimistic Thud driver was one who thought he would die of lung cancer. In fact, the Air Force commissioned a study that showed that during a typical 100-mission tour, an F-105 pilot should expect to get shot down twice and picked up once. At about the time that Tullo got his captain's bars, air rescue planners decided to try to improve the pilots' chances.

On July 27, 1965, Tullo was flying as Dogwood Two in a flight led by his good friend Major Bill Hosmer, a former Thunderbird and the best pilot Tullo had ever flown with. Dogwood was to be the cleanup flight—the last of 24 F-105s, six flights of four, from Korat to hit surface-to-air missile (SAM) sites in North Vietnam. Their job, as cleanup, would be to take out any sites not destroyed by the earlier flights.

The SAM had introduced a new aspect to the war only days before, when

The long-range, armor-plated Sikorsky HH-3C Jolly Green Giant (left) came to the rescue in Vietnam in November 1965. Months before, pilot George Martin (below, center), ad libbing with his cargo version CH-3, flew the helo's first recovery in the North and brought back F-105 pilot Frank Tullo (right).

FRANK TULLO COLLECTION

AP/WIDE WORLD PHOTOS (2)

Loaded with up to 14,000 pounds of ordnance, supersonic F-105 Thuds flew risky missions against enemy defenses.

an F-4 Phantom II became the first to fall to these new weapons. The missiles were fired from within a no-fly zone near Hanoi, previously immune from attack as dictated by rules of engagement. Tullo's flight would be part of the first attack within the no-fly zone and the first major strike on the SAM sites since the Phantom had been downed.

To destroy the missile sites and take out their command and control centers, each Thud was loaded with two pods of 2.75-inch rockets. (They were also equipped with an internal 20-millimeter Gatling cannon.) Along with the rockets, the Thuds carried 450-gallon auxiliary fuel tanks under their wings. Tullo's aircraft, which was scheduled to be flown to Okinawa for maintenance, also carried a 600-gallon tank on its centerline. He'd have to jettison the tank once airborne to stay with the flight.

This was part of a maximum effort involving at least 48 F-105s—24 from Korat and 24 from Takhli—and another 50 or so supporting aircraft. At this early stage of the war—the buildup of U.S. fighters in Thailand and South Vietnam had begun only six months before—tactics and weapons for dealing with SAMs had not been developed. The projected learning curve for the months ahead was nearly vertical.

It was mid-afternoon when Tullo's flight came over the hills from the south to clean up leftover targets. Dogwood flight had been listening to the action on the assigned attack frequency since an in-flight refueling midway en route. From the sound of things, some friendly aircraft were down. As the flight cleared the last ridge at treetop level before arriving at the target area, Hosmer, who was Dogwood lead, exclaimed, "Jesus!"

Working to hold his position on Lead's wing, Tullo managed to steal a look ahead. "I damn near fainted," he told me years later. "To a good Catholic boy, this was the description of hell." The whole valley was a cauldron of flame and smoke from the ordnance dropped by preceding flights, and North Vietnamese Army flak filled the sky. In the five months he had been in the war, Tullo had seen his share of anti-aircraft artillery, but this was the worst yet.

Tactics for dealing with SAMs had not been developed.

Hosmer had the flight on course for the first SAM site they were to check out. Tracers were flying past the canopies and the smell of cordite was strong—the pilots depressurized their cockpits when they neared the target area so that if hit, smoke from an onboard fire would not be drawn inside. Only days before, Tullo had seen a column of smoke stream from his wingman's still-pressurized cockpit after the canopy was jettisoned prior to ejection.

The flight pressed lower. The Thud would do nearly 700 mph on the deck. Tullo was sure they were under 200 feet and was working hard to stay in position on Lead.

Without warning, Hosmer broke hard left, exclaiming "Damn, they just salvoed!" Sometimes SAM batteries would fire all their missiles at once in an effort to save the valuable control vans. Tullo could see only the huge wall of smoke and flame coming at the flight from the NVA guns protecting the SAM sites.

Their tremendous speed caused the flight to turn wide enough to be carried directly over the gunsite. As they passed over, Tullo looked right into the flaming muzzles of a battery of quad guns. They were at 100 feet or lower, and still near 700 mph. He glanced over at Lead to check his position, then back into his cockpit. That's when he noticed the fire warning light.

"Lead, I have a fire light," he radioed.

Three called, "Two, you're on fire. Get out!"

Hosmer kept the flight in the turn, saying, "Two, loosen it up. I'm going to look you over."

Tullo assumed the lead and headed for the mountains in the distance. Hosmer said, "Better clean off the wing, Frank." To give himself more speed and maneuverability, Tullo jettisoned the tanks and rocket pods on his wings and felt the Thud lighten.

Three was calling again, his voice tight with urgency.

"Two, the flames are trailing a good 150 feet behind you. You better get out!" In spite of the fire and the calls from

Three, Tullo felt a sense of well-being. He was still flying, he had control, and he was with Hosmer. Nothing bad would ever happen with Hoz leading. It would work out. The fire would go out, the aircraft would keep flying, he would make it back. They were still over Hanoi. Houses were below them. The mountains to the west, which would come to be known as Thud Ridge, offered refuge. A good bailout area, just in case.

"You better get out, Frank, it's really burning," Hosmer said in a calm voice.

"Negative," Tullo replied. "It's still flying. I've lost the ATM [the noisy auxiliary turbine motor, which provided the Thud's electrical power but left many of the aircraft's pilots with bad hearing], but I've got the standby instruments, and I'm heading for that ridge straight ahead." In the early days, several pilots whose aircraft were on fire ejected over the target and were either killed or taken prisoner. There had been incidents in the Thud's checkered past when a burning aircraft had exploded before the pilot could eject, but many others had flown for a considerable time without blowing up. Many pilots, like Tullo, had decided to take their chances staying with their aircraft as long as they could, rather than eject in the target area.

The ridge was still well ahead of the aircraft. The flight had climbed some but was still very low and being shot at from all quarters. Tullo's aircraft dropped its nose slightly. He pulled back on the stick. No response. He pulled harder. Still nothing. When he heard muffled explosions in the rear of the aircraft, Tullo hit the mike button: "I've gotta go, Lead. I'm losing controls. It's not responding." At 200 feet, there was no time to wait. If the aircraft nosed down, physics would be against him. Even if he managed to eject, he would likely bounce just behind the aircraft, still in the seat. He pulled up the armrests, which jettisoned the canopy, locked his elbows in the proper position, and revealed the trigger that fired the seat.

The results were the most horrific Tullo had ever experienced. At the speed he was moving, the noise, the roar, the buffeting—it was unbelievable. Everything not bolted down in the cockpit went flying past his face. He froze for a matter of seconds before he squeezed the trigger to fire the seat.

> The whole valley was a cauldron of flame and smoke from the ordnance dropped by preceding flights.

The ejection process that followed was so violent that today Tullo's memory is blank of everything that happened immediately after he squeezed the trigger. He doesn't remember leaving the cockpit, the seat separating, or the chute opening. He had the low-level lanyard hooked, which attached the parachute directly to the seat and caused it to deploy almost immediately. After tumbling violently, *whomp!* he was swinging in the chute.

A little battered by the violent ejection, Tullo prepared for the landing. Floating down in the chute was serene and the soft rush of air soothed him. He did not see his aircraft crash. During his descent, he eyed the city of Hanoi about 25 miles away. A small U-shaped

Rescue crews presented a broad target for as long as it took to extract a downed pilot hidden by dense foliage.

farmhouse sat near a clearing, just to the west. He passed below the 100-foot treetops and landed in an area of 10-foot elephant grass.

At that moment, listening to the sound of his flight disappearing to the southwest, the only thing in his mind was that he was on the ground in North Vietnam, armed only with a .38 Special. His first concern was to hide the billowing white parachute. Working hard to control his breathing, he stuffed the parachute under the matted grass and covered it up with dirt. After shedding his harness and survival kit, he removed the emergency radio from his vest, extended the antenna, and prepared to contact Dogwood flight. He could hear them returning, and he had to let them know he was all right.

As the flight drew closer, Tullo turned on the survival radio. Cupping his hand around the mouthpiece, he whispered: "Dogwood Lead, this is Dogwood Two." Hoz responded immediately: "Roger Two, Lead is reading you. We're going to get a fix on your position."

The flight turned toward Tullo, who had landed on a hillside west of Hanoi. He could hear heavy anti-aircraft fire to the east and see puffs of flak dancing around the flight. Within seconds, hot shrapnel began to fall around him.

"Frank, we gotta go. Fuel is getting low, and we've been ordered out of the area. We're gonna get you a chopper." Hosmer's voice dropped: "And, Frank," he said, "this may be an all-nighter."

Tullo rogered Hosmer's message and told him he was going to try to work his way higher up the slope to make the pickup easier. He had no doubt that he would be rescued.

As the sound of Dogwood flight faded to the southwest, Tullo prepared to move up the hill to a better vantage point. He decided to open the survival kit and remove useful equipment. In a normal ejection, once stabilized in the chute and prior to landing, a pilot would reach down and pull a handle on the kit's box to deploy it. It was advisable to deploy the kit prior to landing to avoid possible leg injuries, since the case was hard and fairly heavy. Tullo hadn't had this option because he had ejected at such a low level.

He rotated the kit's red handle, and with a great whooshing roar, a dinghy began to inflate.

The dinghy! He had forgotten all about that! And it was bright yellow! He had to stop the noise. Tullo drew a large survival knife he wore strapped to the leg of his G-suit, threw himself on the dinghy, and began stabbing it. The first two blows merely rebounded. With a final mighty effort, he plunged the knife into the rubber and cut a large hole so the air could escape. With that emergency solved, Tullo lay back to catch his breath and get a drink of water. Then he started up the hill.

USAF (2)

Hard-working crews kept the Jolly Greens flying. Both the CH-3C and its cousin, the HH-3C, were powered by two 1,300-shaft horsepower General Electric T58-GE-1 turboshaft engines.

The elephant grass was so dense that at times he couldn't separate it with his hands and had to climb over the tough, wide blades. After climbing about 50 to 75 feet, he realized he wasn't going to make it to the top. His flightsuit was soaked, and his hands were cut by the sharp edges of the grass. Rather than waste more energy, he flattened out a small space in the grass and faced southeast to have a good view of any threat coming up the slope. Time to set up housekeeping.

Tullo's survival vest and kit included a spare battery for the radio, emergency beeper, day and night flares, pen flares, six rounds of tracer ammo, a "blood chit" printed in several languages that promised rewards for assisting downed American airmen, gold bars for buying freedom, maps, a first aid kit, water purification tablets, two tins of water, two packets of high-energy food, tape, string, 250 feet of rappeling line, a saw, knife, compass, shark repellent, fishing kit, whistle, signalling mirror, sewing kit, and two prophylactics for keeping ammunition or other equipment clean and dry. He extracted the ball ammo from his .38, loaded the tracers, and stuffed everything not immediately useful into the knapsack-type pouch. Then he sat back, tried to relax, and waited for the rescuers he knew would come.

Tullo heard the sound of prop-driven aircraft approaching from the north. He correctly assumed they were Douglas A-1s, or "Spads," as they were called. He stood up and keyed his radio. "This is Dogwood Two, do you read me?"

"Dogwood Two, this is Canasta, and we read you loud and clear. Transmit for bearing." Tullo warned Canasta of the flak to the east, and as advertised, the guns opened up as the aircraft approached Tullo's position. As soon as Tullo could see the aircraft, he began giving vectors. On the second circle, Tullo was looking right up the wing of Canasta, a flight of two Navy A1-Hs. He called, "Canasta, I'm right off your wingtip now." Canasta Lead said, "Gotcha! Don't worry, we're going for a chopper." As the Spads droned out of the area, Tullo felt sure he would be picked up.

Within a few minutes, he heard the unmistakable sound of Thuds. Thinking it could be Hosmer again, he turned on the survival radio and called, "Any F-105 over Vietnam, this is Dogwood Two." An answer came from a flight of two Thuds, which approached his position in a wide sweeping turn from the north. The flight Lead, whose voice Tullo recognized, asked Tullo to pop a smoke flare for location.

"Smoke?" Tullo replied. "Are you out of your mind? There's no way I'm going to pop smoke here!"

The pilot told Tullo to calm down. He had just spotted trucks unloading troops to the south of Tullo's position. He also reassured Tullo that they were working on getting a helicopter to him.

Tullo heard shots. They built to a crescendo, then stopped. The shooting had started at some distance but had grown closer. Soon he was able to hear voices as the troops worked their way up the hillside. He burrowed into the dense grass and waited, his heart pounding. He raised his head and saw an older man about 150 to 175 feet away wearing a cone-shaped straw hat. It was all Tullo could do not to make a run for it, but that was exactly what they wanted him to do. He forced himself to sit quietly. The troops made a lot of noise but they kept moving to the east, down the hill. Silence returned and Tullo continued to wait.

Tullo tried to relax and waited for the rescuers he knew would come.

USAF MUSEUM, WRIGHT-PATTERSON AIR FORCE BASE

The HH-3C's air-refueling capability dramatically increased the Jollys' range and allowed more loiter time.

George Martin was flying his Sikorsky CH-3C helicopter to Lima 36, a remote staging area in Laos about 120 miles from Hanoi, to prepare for another day of rescue alert duty. Only a few weeks before he had been flying cargo support at Eglin Air Force Base in Florida. Today, he was commanding a small detachment of men and helicopters on a 120-day assignment in Viet-

FRANK TULLO COLLECTION

In the relative safety of a forward base in Laos, Tullo (second from left) first told the tale of his ejection near Hanoi.

nam. He and his crew had been tasked to learn a new mission for which they had little preparation.

In 1965, as the number of U.S. airstrikes and reconnaissance missions in Vietnam multiplied, pilots faced the increasing possibility of being downed deep inside Laos or North Vietnam. Crews flying the small and slow Kaman HH-43 Huskie, originally designed as an air-base firefighting and rescue helicopter, were already pushing the aircraft to its limits. There was clearly a need for a faster rescue helicopter with longer legs. The cargo-carrying CH-3C fit the bill, and the Air Force began sending crews from Eglin for specialized training. The crews practiced mountain flying, ground survival, and rescue operations, which involved coordination with controller and escort aircraft. The training was projected to last several months, but the escalating conflict wouldn't wait.

Martin, who was too close to retirement to be selected for the additional training and the accompanying extended tour, was ordered to fill in with 21 men and two CH-3s until the fully trained crews arrived. "I found out Friday afternoon and was gone Sunday evening," Martin says. "It was just like in the movies—I said, 'When do I leave?' They said, 'How fast can you pack?' "

Martin was about to land at an intermediate refueling base when he was asked by radio to divert and try to rescue a downed F-105 pilot. Martin still needed to proceed to Lima 36 to drop off cargo and extra crew. He had to lighten his aircraft to take on as much fuel as possible and still be able to pick up the pilot. "The big consideration in helicopter pickup is gross weight," Martin says. "If you're too heavy to hover, all you can do is fly around and wave at him."

Upon landing at 36, Martin's number two engine warning lights indicated an "overtemp" condition, which meant significant problems, possibly foreign object damage or a compressor stall from air starvation, and under normal circumstances would have grounded the aircraft. The crew looked to Martin for a decision. "Everybody was pretty apprehensive. I told them, 'We're his only hope. If the engine will start again after cool-down, we'll go.' " His crew reluctantly agreed.

There was clearly a need for a faster rescue helicopter with longer legs.

The engine restarted without incident and Martin's CH-3, call sign "Jolly Green One," took off for Hanoi. Martin had no idea where to locate the downed pilot. He was unescorted until he was about 50 miles from Hanoi, at which point he was joined by Canasta flight, flown by Ed Greathouse and Holt Livesay from USS *Midway*'s Attack Squadron 25.

The oppressive heat of the afternoon wore on. Finally, Tullo heard the sound of prop-driven aircraft again. Darkness was about 40 minutes away as he turned on his radio. The aircraft responded immediately. "Dogwood Two, this is Canasta. I have a chopper for you." Seconds later, Canasta flight flew directly over Tullo's position, and there, not far behind, came a helicopter. Tullo was expecting a small chopper, but this one was a big green monster, Martin's Jolly Green, the first in the theater and headed for its first combat recovery—Frank Tullo.

"Dogwood Two, this is Jolly Green. How'm I doing?" Martin said to the man on the ground. He was coming right up the valley from the south-southwest. Tullo said, "You're doing great!" and popped his pen and smoke flares. The chopper's blades made the smoke swirl as Tullo aimed his .38 straight up and fired all six tracer rounds. Crew chief Curtis Pert spotted the pilot through the thick ground cover as soon as the smoke made its way above the trees. As Martin hovered, Pert lowered a "horse collar" sling.

Later, better equipped rescue crews would have a specialized hoist attached to a "jungle penetrator" designed to pierce thick tree canopies. "We just had a jury-rigged cargo winch that you could turn into a 10-cent, Mickey Mouse rescue hoist," Martin says.

On the ground, the downblast was tremendous. Debris flew everywhere,

and the trees and grass were whipping and bending wildly. Tullo holstered his pistol, slung the survival kit over his shoulder, and slipped the horse collar over his head. He gave the crew chief in the door a thumbs-up.

The cable became taut and Tullo began to rise off the ground. After being lifted about 10 feet, the hoist jammed and the cable stopped. The crew chief was giving hand signals Tullo did not understand. Tullo looked up. Pert and pararescueman George Thayer were in the door lowering a rope. The horse collar was cutting off the circulation in Tullo's arms and he was tiring, but he grabbed the rope and tied it around the top of the horse collar.

Finally the chopper began to move and dragged Tullo through some bushes. *Everybody's trying to kill me*, he thought. The Jolly climbed and circled as Pert Thayer struggled with the hoist. The overworked number two engine had begun to overheat and a fire light came on in the Jolly's cockpit. As they circled, Martin hoped that the air flowing through the engine would cool it down and the light might extinguish.

Pert and Thayer were joined by copilot Orville Keese, and the three men strained to pull the dangling man aboard. The pain was becoming so great that Tullo was thinking about dropping from the sling.

Martin spotted a rice paddy next to a house and lowered Tullo to the ground. The exhausted pilot rolled out of the sling as the chopper swung away and landed 50 or 60 feet away from him. Pert and Thayer frantically shouted to Tullo, who sprinted and dove through the door. He could hear an automatic weapon firing and saw both pilots in the helo ducking their heads.

The Jolly had problems: low fuel, a sick engine, darkness, and clouds at altitude. Martin and his crew had been in the war zone slightly more than two weeks and did not even have maps of the area. The crew relied on flares lit inside 55-gallon drums at Lima 36 and the landing lights of hovering helos to find a place to land. "We held only about a quarter of the area around the site," Martin says. "That was the only corridor you could fly through without getting shot at, because the Pathet Lao held the other three-quarters." Martin finally landed with a shaken pilot and just 750 pounds of fuel aboard.

Tullo learned his aircraft was one of six Thuds and one EB-66 electronic countermeasures aircraft shot down that day. Of three surviving pilots, Tullo was the only one rescued—the others were to spend more than seven years as POWs. Tullo returned to a Thunderchief cockpit and completed his tour. His story was later told in *Thunder From Above* by John Morocco.

Tullo's rescue was the farthest north that a successful pickup had been made, thanks to the determination of Martin and his crew and the long range of their CH-3C. It was the first of 1,490 recoveries that Jolly Green Giants would make in Southeast Asia. Soon a dedicated air rescue version would be built, the HH-3C, with in-flight refueling capability, armor plating, a powerful hoist, and shatterproof canopies. However, the Jolly Green Giant would find its ultimate form in the HH-53 Super Jolly, an even larger and more powerful helicopter still flown in various versions today. The technology improved, but rescue crews still had to meet the same basic requirements: a willingness to fly into hostile territory, hover in a big green target, and find a man whose only hope arrived on a cable and sling.

Jolly pilots had to manage their fuel so they weren't too heavy to hover once they found a downed airman.

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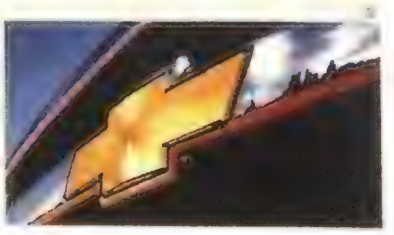


HARD LANDINGS

When your assignment is to put a space probe on another planet, be prepared to sweat.

by Andrew Chaikin *Illustrations by Jan Adkins*

Five minutes. That's how long it will take for Mars Pathfinder to make this Fourth of July either a day of celebration or a day of sorrow for Tony Spear. Just five minutes after speeding into the Martian atmosphere at 17,000 mph, the Pathfinder lander will strike the Red Planet. If it survives, this robotic emissary, which was launched by a Delta rocket last December, will undertake the first exploration of Mars' surface in more than two decades. If it does not, Spear and his team of engineers and scientists—who labored for more than five years to create Pathfinder and send it to Mars—will shoulder one of NASA's greatest disappointments. Of those five minutes, Spear says: "I don't know how I'm going to stand it."

But Spear is only the latest in a long line of engineers to face the uncertainty that precedes every robotic landing on another world. It's an anxiety that began almost four decades ago, when the cold war was being waged in space. In the years after Sputnik, with the United States stinging from one Soviet space first after another, engineers at NASA's Jet Propulsion Laboratory in Pasadena, California, dreamed of scoring a first of their own. Although the Soviets had, in September 1959, already hit the moon with their Luna 2 probe, a true moon landing had yet to be achieved. That was the goal of JPL director William Pickering, who pushed for a mission to deliver a package of scientific instruments to the lunar surface. Early in 1960, NASA headquarters gave formal approval to JPL's Project Ranger.

In terms of physics, the concept for any lander is simple to describe: Just as it reaches its destination, it must undo the work of the launch rocket, canceling the kinetic energy the launch and the gravitational pull its destination give it. But Ranger project manager James Burke and his team found that executing this task was anything but simple. By the time Ranger reached the vicinity of the moon it would be traveling at 4,500 mph. Ideally the lander would settle onto the moon at only a few miles per hour. But this so-called "soft landing" was beyond the reach of existing technology. The best Ranger could do was fire a blast from a solid-fuel braking rocket to slow its descent before its lander simply fell to the surface—a "hard landing."

Solid-fuel rockets were already being used in military airlifts to supplement parachutes when tanks and other massive objects were dropped out of airplanes. But the JPL engineers knew that solid rockets, while simpler than liquid-fuel ones, were also more unpredictable. No one could be sure a solid rocket would deliver the amount of braking needed to counteract all of the lander's excess speed. Furthermore, nobody knew how to predict precisely how fast the spacecraft would be going relative to the moon, or even the exact location of the moon itself.

With all these uncertainties, Burke figured that Ranger might strike the moon at speeds up to 200 mph. He and his team began talking about developing a rugged spherical capsule capable of withstanding such an impact. If this "survival package" seemed a less than elegant plan for humanity's first landing on the moon, Burke didn't mind. "All we were thinking about," he says, "was 'Let's get a transmitter down so we can prove we're there.' "

But how to protect sensitive scientific instruments from a crash as violent as an Indy race car hitting a concrete wall? To identify the best energy absorber, a variety of materials, including aluminum honeycomb, cardboard, and, in Burke's words, "anything crushable," were subjected to tests such as being dropped from a helicopter and slammed around with laboratory equipment. The victor, by a surprisingly wide margin, proved to be blocks of balsa wood, oriented with the end grain radiating out around the sphere for maximum energy absorption.

By the summer of 1960, a 26-inch-diameter sphere weighing 92 pounds began to take shape at a division of the Ford Motor Company in Newport Beach, California. Attached to the capsule would be a solid-fuel retrorocket, which was to ignite when Ranger was 10 miles above the moon. Ten seconds later, after slowing the

lander almost to a hover, the rocket would burn out and be cast off. Pulled by the moon's gentle gravity, the sphere would fall the remaining 1,100 feet to the surface, striking at a speed of about 75 mph. Cushioned by a six-inch layer of balsa wood, the lander would bump and roll to a stop. Inside, floating on a thin layer of water, a one-foot-diameter fiberglass sphere containing a seismometer, radio, and batteries would right itself and begin transmitting.

But the lander was never able to prove it was up to the task. Rangers 1 through 6, including the only three to carry survival packages, all failed. Several missed the moon because of malfunctions in the Atlas Agena launcher. Launch calculations showed that Ranger 4 reached the lunar surface, but the spacecraft malfunctioned shortly after leaving Earth in April 1962 and was unable to return data. Although Rangers 7 through 9 were successful, taking high-resolution photographs on the way down to a crash-landing on the moon, none carried survival packages—in part because JPL was by then working on a lunar lander called Surveyor.

Looking back, Burke sees the Ranger lander as a challenge undertaken before its time. "We were trying something that was too complicated," he says. "Our reach was exceeding our grasp."

But Surveyor made Ranger look simple; it would have to execute the first soft landing. Surveyor would build on Ranger's braking technology, using a solid-fuel rocket to slow from an initial descent at more than 6,000 mph to 240 mph. However, the lander would have to aim the thrust of its braking rocket directly along its flight path to avoid tumbling.

The task was daunting. "We were starting essentially from scratch," says engineer Leo Stoolman, who managed Surveyor's design and construction at Hughes Aircraft in El Segundo, California. When the performance of the new Atlas-Centaur launch vehicle fell short of predictions, design teams were forced to trim hundreds of pounds from Surveyor's allowable weight. More than 60 percent of the spacecraft's final 2,200-pound weight went to the braking rocket; what remained was barely enough to carry out a scientific mission after landing.

PATHFINDER'S DESCENT

Surveyor's braking rocket was so heavy because it had to deliver up to 10,000 pounds of thrust, the cost of counteracting energy rather than absorbing it, as Ranger did. To guarantee that the rocket's thrust travel as precisely through Surveyor's center of gravity as possible, engineers tried to make the rocket's nozzle perfectly symmetrical and aligned with the rocket's center of gravity. "It looked like it ought to be doable," Stoolman remembers, but there was no way to simulate accurately enough to be sure.

Then, at about 25,000 feet above the moon's surface, Surveyor would use small, liquid-fuel rockets to slow to about 8 mph in a vertical descent. The spacecraft would rely on these rockets, called vernier engines, for both control and descent the rest of the trip down. Their control system would use signals from a radar altimeter to measure distance from the surface and a Doppler radar to measure speed. The radars, which used new technology, also caused their share of headaches. And the verniers' development problems were so distressing that in 1964 JPL canceled its contract with Thiokol Chemical's Reaction Motors Division—only to reaward it a short time later, after the company continued working on the engines and

made promising advances. With so many problems, says Stoolman, "we were running scared all the time. We didn't take anything for granted."

Technical burdens aside, one unknown loomed larger than any other: the nature of the moon's surface (see "A Smooth Spot in Tranquility," June/July 1989). Faced with uncertainty, the Surveyor teams designed the lander for a range of conditions. To absorb an impact on hard ground the three landing legs were fitted with shock absorbers, the footpads were made of crushable aluminum honeycomb, and three more honeycomb blocks were mounted underneath the craft's spindly frame. If, on the other hand, Surveyor encountered a dust layer several feet thick, as one scientist predicted, the engineers hoped its oversize footpads and wide body might act like snowshoes to keep it from sinking too far.

The Surveyor teams weren't the only ones grappling with unknowns. By this time NASA had been directed to put a man on the moon; Ranger and Surveyor were officially Apollo's advance team. But there were times when the NASA engineers working on Apollo seemed uninterested in Surveyor or even disdainful, a reflection of the rivalry between the space agency's manned and unmanned programs. Late in 1961 a Surveyor team visited NASA's Langley Research Center in Virginia to ask what their spacecraft could do to help Apollo. One Langley engineer responded, "Crash into the moon and smash all to hell." At least then, he added, they would know the surface was solid.

Surveyor engineers may have recalled that comment in April 1964, when a test version of the spacecraft, outfitted with working radars and vernier engines, was suspended from a balloon and lofted 1,500 feet above the New Mexico desert for a test of the landing system. Before the test could begin, a nearby electrical storm triggered the balloon's electronic release mechanism and the test Surveyor fell to the desert floor and broke into pieces.

For JPL, Surveyor's troubles worsened an already dire situation. Ranger 6 had failed that January. The bad news persisted even after Ranger 7 finally triumphed in July: A second Surveyor drop test failed in October because of a series of malfunctions. When engineer Robert Parks took over as project manager of the Surveyor effort, his colleagues at the lab offered condolences. "They thought I had taken on an impossible task," he says.

The delays cost the Surveyor team the moon race. On February 4, 1966, a Soviet soft-lander called Luna 9 alighted on the plains of the moon's Ocean of Storms and radioed back pictures. Luna didn't match Surveyor's technical sophistication, but that didn't lessen the sting at JPL. NASA's own attempt was only four months away.

On June 1, less than three days after a flawless launch, Surveyor 1 reached the vicinity of the moon. In Pasadena it was past 11 p.m., but JPL was alive with activity. Inside the lab's new mission control building, Parks and his team knew that everything in the landing sequence would happen automatically; all they could do was wait. Less than 50 miles above the moon, Surveyor 1's braking rocket fired a 40-second blast, then fell away. To everyone's relief, telemetry showed the lander wasn't tumbling. At 25,000 feet the verniers took over. A mission commentator called out the diminishing altitude: 1,000 feet, then 500, then 50, then 12—and finally "Touchdown."

In mission control, no one could believe it—well, almost no one. "My feeling," says engineer Gene Giberson, "was, 'Yep, we did it, we did exact-

ly what we said we were going to do.' " Geologist Gene Shoemaker, a Ranger veteran leading one of the Surveyor science teams, recalls having a different reaction: "My God! It landed!

"We were all shell-shocked from Ranger," Shoemaker says. "Hell, I wouldn't have given you a 10 percent chance that Surveyor 1 was going to land." Not only had Surveyor 1 landed on the Ocean of Storms, it had done so at a comfortable 10 mph. Half an hour later, the first television images began to appear on the monitors at JPL, showing a round footpad perched on a dusty but firm moonscape. As Surveyor's pictures revealed a 100-foot crater rimmed with boulders, it became clear that getting Surveyor down safely had taken more than ingenuity. "I think we were all aware that it was going to be a matter of luck," Shoemaker says.

For the most part, Surveyor's luck held. Six more missions followed; all but two were successful. For the program's climax in January 1968, Surveyor 7 made the riskiest landing of all, touching down in the rugged highlands next to the giant crater Tycho. Eighteen months later, when the Apollo 11 astronauts descended to the Sea of Tranquillity, Neil Armstrong had to take over manual control from the onboard computer, which was aiming for a giant, boulder-strewn crater. Today Gene Shoemaker marvels at the way things turned out. "Every time we landed blind with Surveyor and had a chance to land, we landed successfully," he says. "As luck would have it, you really had to have the astronaut there to land the sucker on [Apollo] 11. Surveyor would've been a gone gosling."

By the time of Apollo 11's success, NASA was planning to attempt a landing far beyond any astronaut's reach. Since 1962 the agency had been studying how to put a spacecraft on Mars. Everything about the idea overshadowed Surveyor's challenges, beginning with Mars' vast distance. The trip from Earth would span 10 months and more than 200 million miles, requiring a more self-reliant and more reliable spacecraft. Compared with all previous landers, any Mars lander worth sending would be not only more complex but heavier, and would necessitate a more powerful booster. The Martian gravity, about three times that of the moon, required the descending probe to withstand greater forces of deceleration. But to scientists, the Red Planet's pull was irresistible.

At the Langley Research Center, the effort was led by engineer Jim Martin, whose formidable presence and military-style crewcut won him nicknames like "the Prussian General." Viking needed a tough manager; in addition to being the most challenging robotic mission NASA had ever planned, the Mars landing was the most expensive.

Although the Viking landers were similar to their lunar predecessors, Martin's teams looked to the Apollo lunar module rather than Surveyor for technological hand-me-downs. Viking, like Apollo, would also use an orbiter from which the lander would be dispatched. Mars, however, has something the moon lacks: an atmosphere. From the Mariner Mars flyby probes, which had begun in the mid-1960s, scientists knew that the planet's carbon dioxide envelope was tenuous, with a surface pressure only a small fraction of that on Earth. Still, it was enough to require that Viking use a heat shield, followed by a parachute to decelerate. The tried-and-true combination of radar and vernier rockets would take care of the rest.

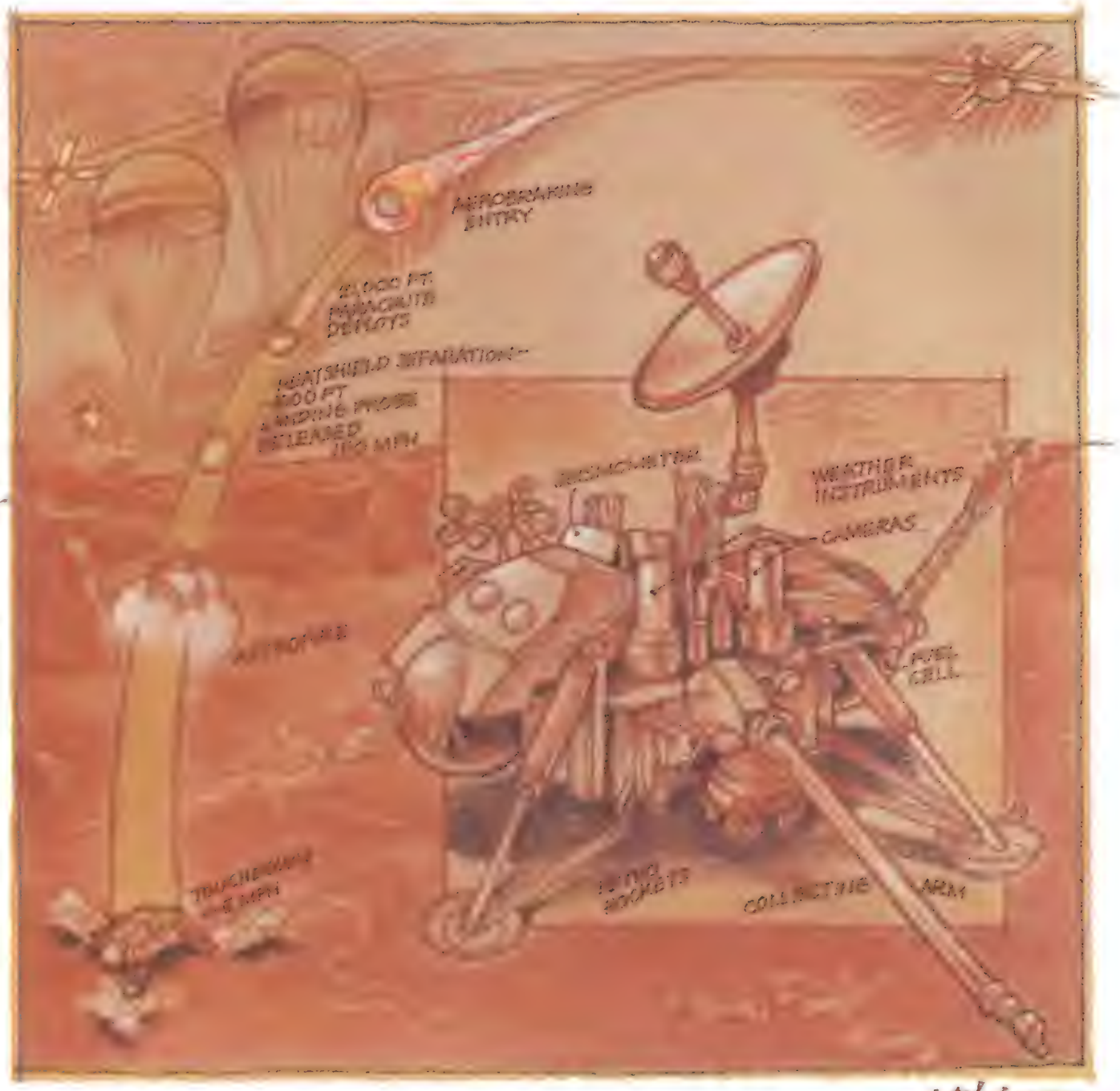
Even more troublesome than getting

to the surface of Mars was keeping stowaways from going along. A spacecraft created to detect Martian microbes would have to be sterilized before leaving Earth. For Viking, that meant baking the entire lander for 40 hours at temperatures up to 234 degrees Fahrenheit. That played havoc with microelectronic components—and both landers were full of them, including a miniature biological laboratory in each. Just as vulnerable were the twin onboard computers, each possessing 18,000 words of memory in a container roughly the size of an overnight bag—a marvel by early-1970s standards. The entire descent to Mars would be controlled by one of those computers, but sterilization almost did them in; in one heat test after another the magnetic-wire memory failed. The computer occupied a spot on Jim Martin's infamous Top Ten List of problems for two and a half years, until engineers at Honeywell Aerospace finally perfected it.

In the end, Martin estimates, sterilization soaked up a quarter of the $930 million that the four Viking spacecraft cost all together—about $3 billion in current dollars. "They wanted the best," he says of NASA headquarters.

Even so, some inside the project feared that all that money, time, and effort might be for naught. The odds weren't promising. Not long after the Vikings left Earth in August and September of 1975, project scientist Gerry Soffen asked chief engineer Israel Taback what he thought the chances were of one lander getting down safely. When Taback estimated the odds at only 30 to 40 percent, Soffen says, "I was surprised they were that good!" He fully expected that Viking 1 would crash; then everyone would try to figure out what went wrong in time for Viking 2's attempt weeks later.

Jim Martin was more optimistic—but not much more. During a meeting with Viking scientists the following spring just before the spacecraft's encounter with Mars, Martin had said the odds of success were 50 percent. One scientist threw up his hands and wondered aloud why he had invested a decade of his life in a project with so little chance of succeeding. Martin explained that this was why there were two sets of spacecraft.



Viking

The Soviets knew the risks all too well. By 1976 they had tried as many as six times to place a lander on Mars without real success. In 1971 the Mars 3 lander reached the surface and transmitted for 20 seconds, then mysteriously died. Two years later Mars 7 missed the planet by 800 miles because of an internal malfunction; three days after that, Mars 6 crashed on the surface—and gave Viking the chance to make history.

On June 19, 1976, Viking 1 went into orbit around Mars. Three days later, when the orbiter's first images were received at JPL, scientists were stunned—not only because the pictures showed more detail than any previous views of Mars, but because the planned landing site was far rougher than anyone had expected. So began a feverish effort to find a safe landing site, using the Viking 1 orbiter's cameras. Graduate students poured over each new image with magnifiers, tallying the smallest boulders and craters for hazard analysis. Scientists argued about how to interpret radar soundings made with Earth-based radio telescopes.

Viking's earliest possible landing date, by coincidence, had turned out to be July 4. Now NASA was counting on the landing to be part of the nation's bicentennial celebration. But as the hunt for a new landing site dragged on, Martin informed NASA administrator James Fletcher that the July 4th date was out of the question. By chance, Viking 1

was ready to land on a day that had its own significance: July 20, seven years to the day after the first humans had landed on the moon.

The moment of truth came just after 5 a.m. Pacific time, as the lander, encased in its heat-protective aeroshell, sped into the Martian atmosphere. Within minutes deceleration forces on the lander built to 8.4 Gs, then slacked off somewhat as the aeroshell sped toward Mars' Chryse Plains. At 21,000 feet, with Viking still traveling at supersonic speed, a mortar fired to deploy the parachute. Less than a minute later the parachute was cast off as the lander's three vernier engines ignited.

Like their Surveyor predecessors, Jim Martin and his people were reduced to waiting. Because Viking's radio signals took 19 minutes to reach Earth, it was a bit like sweating out the delayed broadcast of a crucial football game; by the time the first descent data appeared on their screens they knew that Viking would have already landed—or crashed. Then came exultant words: "Touchdown! We have touchdown!"

When the first image from the surface of Mars appeared on the monitors, NASA knew it had been lucky again: A boulder almost as big as the lander stood only 30 feet away. Less than seven weeks later, Viking 2 alighted safely on Mars' Utopia Plains, but instead of the sand dunes the geologists had promised, its pictures showed a jumble of rocks, much to Martin's chagrin. But no matter: The Mars landings had been more successful than almost anyone had dared hope.

Even so, another 16 years would pass before NASA decided to return to the surface of Mars. Not until 1992 did the space agency approve Mars Pathfinder as the first of a series of robotic landings. As project manager Tony Spear soon learned, Pathfinder was expected to live up to its name and test a new type of landing system. Spear's assignment got even tougher when he was given a budget ceiling of $150 million in 1992 dollars—five percent of Viking's cost. Says Spear, "We had no idea whether we could do that or not."

Whatever they lacked in certainty Spear's people made up for in motivation. Pathfinder represents a new generation of scientists and engineers, exemplified by 36-year-old Sam Thurman. An engineer who coordinated the design of Pathfinder's entry, descent, and landing systems, Thurman remembers being galvanized by the Viking landings as a teenager. When he came to JPL 10 years ago, nothing like a Mars lander was in the works. "I was really getting worried for a while that the most exciting era in the space program had come and gone, and I missed it," Thurman says. Pathfinder was the opportunity he had been waiting for.

Thurman and his teammates had only 38 months to redefine the art of landing on Mars, and they would have to do it with a fraction of Viking's workforce. They also had to stay motivated in the face of some healthy criticism from a NASA review panel that included Viking veterans like Jim Martin. (Engineers who have already braved the challenges of landing on another world can be tough to impress. At a 20th anniversary reunion last summer at the National Air and Space Museum, one Viking veteran expressed doubt that the public would be excited about Pathfinder or its rover, which he puckishly dismissed as "a Tonka toy." Gesturing toward a Viking replica, he beamed with pride. "Viking was big! That was a real lander.") "They were brutal," Pathfinder deputy project manager Brian Muirhead recalls wryly. "They were sharp guys and they were getting paid to beat us up. I think they sensed that it was for our benefit."

Gesturing toward a Viking replica, one Viking veteran beamed with pride. "Viking was big! That was a real lander."

By 1993, when work on Pathfinder began, the reviewers had told Spear and his team that the only way to avoid smashing through their cost ceiling was to simplify as much as possible. There would be no orbiter; like Surveyor, Pathfinder would fly directly to the surface. (An orbiter launched by NASA last November, Mars Global Surveyor, will reach Mars in September to provide a detailed look at the planet from orbit. But by then Spears hopes Pathfinder will be part of the Martian scenery.)

As much as possible, the design of the lander's heat shield and parachute are borrowed from Viking. But the landing system is entirely different: There is no retrorocket and no radar-controlled vernier engines. Instead, Spear's team chose an approach reminiscent of Ranger's survival package. Pathfinder will simply fall onto the surface, protected not by balsa wood but by a set of pressurized airbags. Airbags had been studied for space probes by JPL engineers as early as 1966. Now, Spear hoped, they would be not only the most rugged solution, but the cheapest.

Like every landing project before them, the Pathfinder team found that nothing was easy. Yes, technology had come a long way since Viking, and Pathfinder's computers and electronic components were cheaper to build. Then, too, the requirement for pre-launch sterilization was dropped, because Viking data suggested that the Martian surface is not only lifeless but chemically hostile to organic matter. And although the Viking heat shield and parachute designs had to be modified for Pathfinder, Spear says using them "saved us a ton of money." But hopes of building Pathfinder without a retrorocket proved too optimistic; without one, calculations showed, the lander would hit the surface too fast for airbags to protect it. A trio of small solid-fuel rockets had to be added, along with a simple radar altimeter to signal when they should ignite.

Meanwhile, work went ahead on the

airbags, which turned out to be the biggest headache of all. By the end of 1994 a group led by JPL's Tom Rivellini had worked out their basic design. The spacecraft would be shaped like a tetrahedron, with three sides that opened like flower petals to let it right itself after landing. Each petal would contain an airbag with six spherical lobes that would be deployed just before landing. Fully inflated, the airbags would make Pathfinder resemble a bunch of party balloons. Of course, they would have to be enormously more rugged; calculations showed that the 800-pound lander could strike the surface at 60 mph.

Rivellini's group had selected a material they felt was up to the task: a fabric called Vectran, an exotic cousin of the more familiar Kevlar used in bulletproof vests. To fabricate the bags, they chose the Delaware-based ILC Corporation, whose products include NASA spacesuits. But it didn't take long for frustration to set in. Vectran's incredible resistance to stretching—the source of its strength—made it extremely intolerant of any errors in the shape of a seam. The first bags stitched together at ILC broke apart when they were pressurized.

Even as that problem was solved, it became apparent that Vectran had another weakness, this one potentially fatal. Although tests showed that a Vectran airbag would resist being punctured if a sharp rock were pushed straight into it, a rock dragged across the fabric would disrupt the weave of the fibers, making the bag dramatically more vulnerable to tearing. For that reason, it was crucial that Pathfinder strike the surface with as little horizontal motion as possible. The problem was, the Martian winds might not cooperate. Wind gusts hadn't been a problem for Viking, whose vernier engines were able to counteract them. But Pathfinder would make its final descent suspended from a parachute and aeroshell at the end of a 65-foot tether called a bridle. Blowing winds could make the lander swing like a pendulum, giving it horizontal speed when the bridle is cut. Even worse, a gust could tip the aeroshell at the moment the retrorockets fire, propelling Pathfinder toward the ground at a shallow angle.

Fortunately, there was a tool that no previous landing project had available. Sam Thurman had created a computer program capable of simulating the entire landing sequence. It showed that the parachute-bridle-lander combination would respond to winds not by swinging from side to side but by vibrating like a plucked guitar string, with the lander nearly unaffected. And if the aeroshell tipped, Thurman found, it would quickly right itself.

> "We realized we didn't want a regular airbag," says Pathfinder's Rob Manning; "we wanted a Michelin tire."

Still, the risk of horizontal speed at impact continued to cause worry. Says JPL's Rob Manning, the engineer in charge of getting Pathfinder down safely, "We realized we didn't want a regular airbag—we wanted a Michelin tire." Or at least something as strong as a steel-belted radial; the airbags also had to be small enough to be packed with the lander inside its aeroshell, and light enough not to exceed Pathfinder's stringent weight limits.

In late 1994, Rivellini's group began conducting drop tests of the bags with a model lander. To simulate Martian atmospheric surface pressure—only 0.7 percent that on Earth—Rivellini's group turned to the largest vacuum chamber in the country, near Sandusky, Ohio, operated by NASA's Lewis Research Center. Inside the cavernous chamber, a model Pathfinder was suspended 80 feet above the floor, connected to a set of giant bungee cords that would allow it to plunge downward until it crashed into a tilted platform studded with sharp rocks.

Just as Rivellini had feared, the rocks tore the airbags, even though the bags had been covered with a second layer of material to resist abrasion. He still sounds amazed when he talks about how badly the Vectran fared. After one run at speeds approaching those of actual touchdown, "it looked like a bear walked up to this thing with its claws and just shredded the hell out of it," Rivellini recalls.

Fortunately, ILC seamstress Eleanor Foraker—who had stitched the moon suits worn by Neil Armstrong and Buzz Aldrin—was on hand to make repairs at a moment's notice. That was no easy task; Foraker had to use special ceramic shears for the job. As Rob Manning explains: "You can't use scissors on this stuff." And fabric designed not to be penetrated was "godawful to stitch," Rivellini adds.

The failures continued into the summer of 1995, with time running out to build and test the lander's components. No computer simulation could solve the airbag problems; Rivellini's group had to rely on trial and error as they experimented with different thicknesses and densities of fabric. Finally they hit on a breakthrough: Multiple layers of lightweight fabric worked better than a single heavy layer.

Even as this hopeful sign emerged, a slew of other airbag-related problems demanded solutions. How would the bags be packed into the tiny space between the lander and its aeroshell? At ILC, a former Air Force paratrooper devised a folding scheme. What about inflating them quickly and safely? That called for hot-gas generators, which burn the same type of propellant used for the retrorockets. Rivellini's group knew Pathfinder would land during the Martian nighttime, with temperatures hovering at 112 degrees below zero. As the gas inside the bags chilled, they would lose pressure in moments. To prevent this, a second set of gas generators was added. Of course, the bags would have to be deflated after landing. And finally, Rivellini had to solve a prob-

lem that some at JPL predicted would be Pathfinder's undoing: how to retract the deflated bags so that the lander could open its petals and begin operating. After a series of low-tech experiments ("trash bags," Rivellini explains) he devised a set of Vectran cords to be routed through loops attached to the bags' inner walls; after touchdown the cords will be pulled into the lander using a winch.

By the end of 1995 everything had come together. Rivellini and his colleagues had created a bag that didn't break, with up to four layers of Vectran in the most vulnerable places. In August 1996 Pathfinder was shipped to Cape Canaveral to be prepared for its December launch. Its next stop would be the mouth of the Martian channel called Ares Valley, the very place Viking 1 was originally slated to land. All the ingredients seemed to be in place for a bold and ambitious landing, if that is what the space agency is looking for. But as Tony Spear recalls, one high-level NASA manager seemed to have mixed feelings about that: "He told me, 'Don't you dare fail. If you do, I'll shoot you on the [JPL] mall.' "

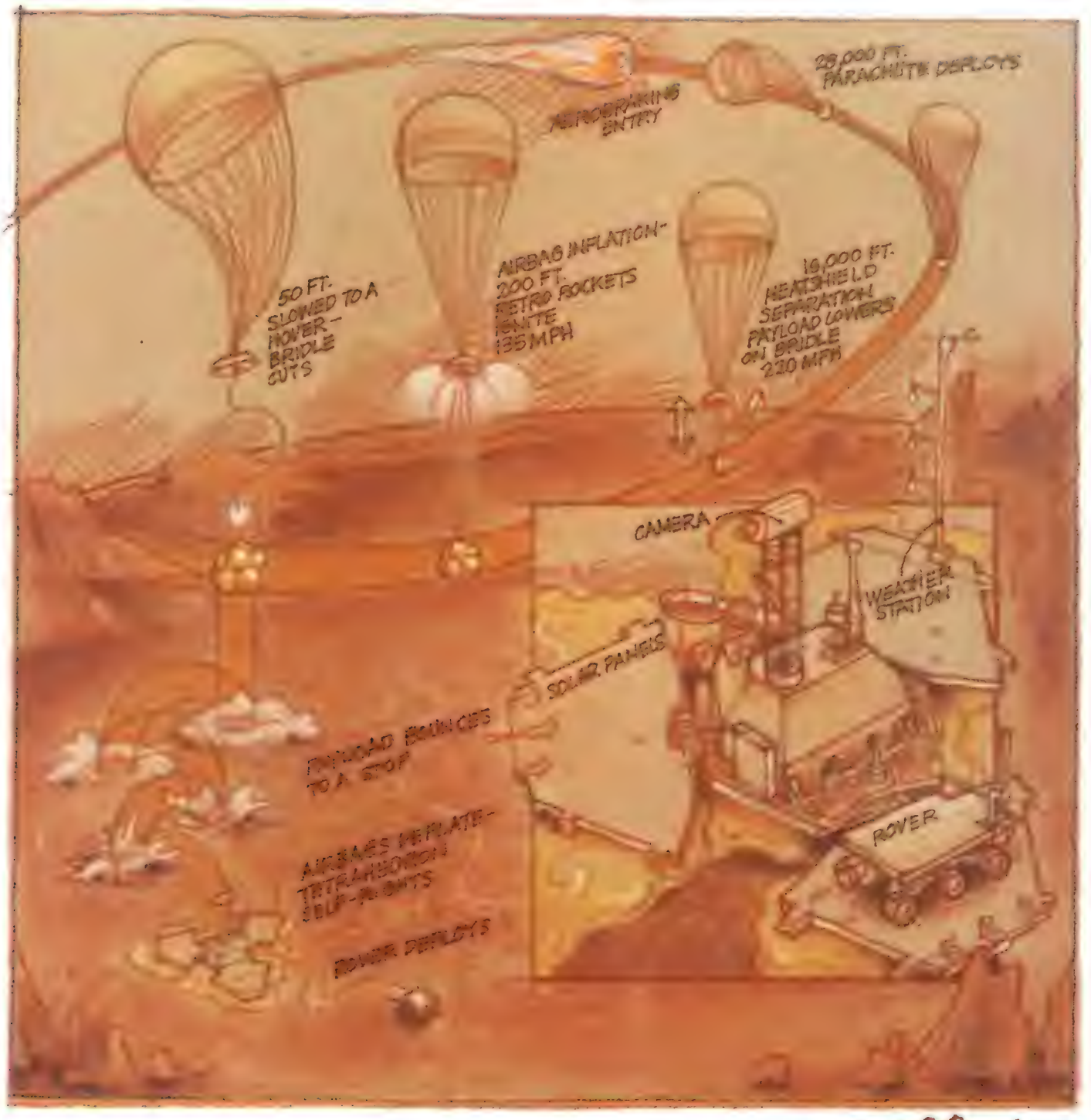
Jim Martin, who understands that kind of pressure, nevertheless has doubts about whether Pathfinder will succeed. "If I had to put a probability on it," he says, "I'd have a problem." Much of that familiar uncertainty, Martin says, could be avoided if future landers had some kind of hazard avoidance system, borrowing from the technology now used in "smart" bombs and missiles. It would be expensive, Martin realizes, but "having a failed lander mission is not cheap either."

There is much at stake beyond Mars Pathfinder. In 1998 NASA will launch a lander resembling a smaller version of Viking to set down near the ice cap at the planet's south pole. And as early as 2005 will come the Holy Grail of planetary exploration, a mission to retrieve a sample of Martian rock and soil. Now that scientists may have discovered evidence of fossil life inside a meteorite from Mars, there is more interest than ever in a sample-return mission, an engineering task that presents its own knotty problems. The sample-return lander may use some combination of the techniques worked out for Pathfinder and the Mars '98 lander.

But Tony Spear won't be thinking about any of that on July 4, as Pathfinder comes screaming into the Martian atmosphere. Spear, like everyone involved, knows that in many ways Pathfinder is the most complex lander yet devised. After all the testing his team has done, he says, he is confident that the fast-paced events in Pathfinder's descent will all go off without a hitch, as they must. But when the time comes, they will still seem to take forever, as Pathfinder endures the heat of reentry, deploys its parachute, and lowers itself to the end of its bridle.

Just eight seconds away from impact, the airbags will inflate—explosively, in an instant. Four seconds later the retrorockets will ignite, lighting up the Martian night with their own Fourth of July fireworks, to slow the lander to a halt a little less than 50 feet above the ground. Severing the bridle, Pathfinder will fall onto Mars, bouncing for perhaps two minutes before coming to a stop, its 200 million-mile journey finally over. Just as their predecessors did 21 years before, Spear's team will have to wait long minutes for the radio signals to travel to Earth before they know if they were successful. Hours later, as the sun rises over Ares Valley, Pathfinder will come to life and deploy a 22-pound rover called Sojourner, and the exploration of Mars will begin again.

Will it work? "Yes," says Spear without equivocation. "But I'm still scared to death."



OUR EXPERTS SELECT THE HOMELIEST AIRCRAFT EVER BUILT.

Beauty is skin deep, the saying goes, but ugly goes all the way to the bone. So it is with this gallery of eyesores, where often the trouble began with the skeleton.

PLUG-UGLY

When it comes to producing ugly airplanes, no one nation has the edge. But some do have specialties. National Air and Space Museum archivist Brian Nicklas has formulated Nicklas' Law of Aircraft Identification, whereby: "If it's ugly, it's British; if it's weird, it's French; and if it's ugly and weird, it's Russian."

Nor are bad looks confined to any one era or aircraft type. One of our panel of experts, Cam Martin of the NASA-Dryden Flight Research Center, notes: "I gave amnesty to the early 1900s, given the state of the art, but my picks were created by a generation who should have known better."

SIEMENS-SCHUCKERT BULLDOG

PETER M. GROSZ ARCO COLLECTION

Siemens-Schuckert Bulldog
Germany
Nominated by Peter M. Grosz, aviation historian

"Its overall ugly shape totally belies what an airplane should be," says Peter Grosz. The Bulldog was designed by Swedish engineer Villehad Forssman for a Prussian prince-pilot early in World War I. Only two were built, one with a Siemens-Halske rotary engine, pictured here, the other with a Mercedes inline engine, each 100-horsepower. Grosz surmises that the German markings were added to the Bulldog when it was temporarily impressed into service. The aircraft was considered vastly underpowered and very quickly wore out its welcome.

Blackburn Blackburn II
United Kingdom (England)
Nominated by Dan Hagedorn, reference team leader, National Air and Space Museum archives

The manufacturer must not have thought much of this plodding single-engine torpedo bomber; the company didn't even bother to come up with a real name for it. The Blackburn Blackburn II performed carrier landings during the 1920s. "In the dual-control trainer variant," writes Dan Hagedorn, "the front fuselage was widened to accommodate pupil and instructor. Unfortunately, drag was increased to such an extent that the whole of the runway (600 yards) was needed to 'unstick' and the initial rate of climb was a sizzling 100 feet per minute. Not the flight characteristics one would wish for in a carrier-borne aircraft.

"English aviation historian A.J. Jackson stated that 'functional considerations took absolute priority over refinement of aerodynamic shape, so that [the] Blackburn was little short of grotesque in appearance, ungainly, and slow in the air.' Despite this handicap, it was described as 'very successful' and remained in service for almost a decade."

RUSSELL MUNSON

PZL-104 Wilga
Poland
Nominated by the staff of *Air & Space/ Smithsonian*

The skinny-legged, knock-kneed Wilga has withstood the test of time: It's just as homely today as when it debuted in 1962 to howls of laughter from aviation writers, to whom the Wilga was the goofiest-looking thing since the flying car. More than a thousand examples of this short-takeoff utility aircraft have been sold as glider and banner towers, ag-planes, patrollers, and aerial ambulances. The trailing-beam landing gear cushions hard landings, making the Wilga an ideal though gangly bushplane.

Northrop P-61 Black Widow
United States
Nominated by Air Vice Marshal Ron Dick (Royal Air Force, ret.)

Its sinister name alone is enough to qualify the Black Widow for our list, but its pitch-black paint scheme, ideal for its nighttime missions, as well as its misshapen and truncated fuselage, seals its fate as the best World War II aircraft for this gallery. The twin-boom arrangement resembles that of the revered Lockheed P-38 Lightning, but all similarity ends there: The P-38's fuselage tapered smoothly into the wing's trailing edge, whereas the P-61's hangs off the trailing edge like an unfinished detail. The Black Widow's nose is classic anteater.

Handley Page Heyford
United Kingdom (England)
Nominated by Don Lopez, deputy director, National Air and Space Museum

NASM

According to Owen Thetford's *Aircraft of the Royal Air Force*, "The Heyford's most notable feature was the attachment of its fuselage to the upper...wings. This brought the lower wing close to the ground, which facilitated rapid rearming, as the bomb-load was stowed inside the thickened centre-section." Says Don Lopez, "It's the most ungainly looking thing I've ever seen. You could easily get killed just falling out of the cockpit." The last of the Royal Air Force's biplane heavy bombers began service in 1933, and, to the relief of aviation aesthetes, was laid to rest in 1941.

NASM

McDonnell XF-85 Goblin
United States
Nominated by Cam Martin, external affairs office, NASA-Dryden Flight Research Center; and the history office, Air Force Flight Test Center, Edwards Air Force Base, California

You'd think any airplane this petite would qualify for the adjective "cute." Not the Goblin. Diminutive as it was, it was completely charmless.

Designed in the later years of World War II, the malignant-looking Goblin was a parasite fighter that was to be carried by a host B-29, B-35, or B-36 heavy bomber. Only two were built, and neither became operational. The program was canceled in 1949.

When asked "What's the ugliest part of it?" Cam Martin replies: "1. The outside. 2. The empennage. (All of the tail feathers stick up like exclamation points as if to say 'Hey! *This* is the back!')"

KALININ K-7

NASM

REPUBLIC XF-91

Republic XF-91
United States
Nominated by the history office, Air Force Flight Test Center, Edwards Air Force Base, California

Republic's XF-91 was one of the United States' earliest attempts to mate rocket engines to aircraft. The Thunderceptor, a painfully contrived name, employed a turbojet engine and four rocket engines along with several other eccentricities, the strangest of which was the inverse taper of its variable-sweep wings—they were narrower at the root than they were at the tip.

In 1951 the XF-91 made history by exceeding Mach 1 in level flight, the first U.S. combat aircraft to do so. But Republic's ugly duckling never saw production, and in 1953, North American's F-100 Super Sabre claimed the honor of being the premier supersonic fighter.

For more eyesores, visit the Web at www.airspacemag.com/supp/JJ97/uglies.html

G.F. PETROV VIA RUSSIAN AVIATION RESEARCH TRUST

Kalinin K-7
Soviet Union
Nominated by Air Vice Marshal Ron Dick (Royal Air Force, ret.)

"If there is a certain greatness to being truly grotesque, the K-7 surely approached a pinnacle of aeronautical achievement," writes Ron Dick. "Prognathous with beetling brows, the K-7 had a strained expression, which was hardly surprising given that six 750-horsepower engines were all that was available to haul along a wing thicker than Lenin's tomb and wheel fairings which could have doubled as landing craft. An elliptical wing with the dimensions of the Black Sea sprouted aileron tabs like boardwalks, while twin booms stretched out feebly to hold up an inadequate tail some distance to the rear."

The K-7 bomber was completed in 1933, and according to Bill Gunston's recent book *Back to the Drawing Board* (Motorbooks, 1996): "[I]t was soon obvious that at particular engine speeds...the booms and tail were resonating badly. The problem was quickly alleviated by opening or closing the throttles, but then it would appear again at a different engine speed." Designer Konstantin Kalinin tried bulking up the booms with steel ("A few extra tons were nothing to the K-7," Gunston notes dryly), but on the ninth flight, vibration again set in, causing the K-7 to dive into the ground. Fifteen people on board the monstrous craft were killed.

NASM

Farman Jabiru
France
Nominated by Ron Davies, curator of air transport, National Air and Space Museum

In *Back to the Drawing Board*, Bill Gunston writes: "all the F.121 Jabirus were...monoplanes of grotesquely short spans.... Indeed, most things about the Jabiru seemed unnatural." Most incarnations of this mid-1920s airliner had four engines in tandem pairs; the F.4X pictured was an aberration of an aberration, with its nose removed to accommodate the propellers of three 300-horsepower engines. When asked for commentary on the Jabiru's unique appearance, Davies says only "Words fail me."

Shorts Skyvan
United Kingdom (Ireland)
Nominated by Cam Martin and Air Vice Marshal Ron Dick (Royal Air Force, ret.)

Jane's *All the World's Aircraft* calls this early-1960s airplane a "light civil or military transport," but there's nothing light-looking about the Skyvan. It looks like some kind of very dense British baked good (an impression bolstered by a reference in Jane's to "a batch of 30 Skyvans...being laid down").

"Uncompromisingly chunky and angular, its freight container body hangs from wings which could have been shaped in a sawmill," writes Ron Dick, "and its twin fins were mere upright planks tacked on as if in afterthought."

NASM

PETER M. GROSZ AERO COLLECTION

Linke-Hofmann R I
Germany
Nominated by Peter Jakab, curator of aeronautics, National Air and Space Museum; and aviation illustrator John Batchelor

Why is it not surprising that Linke-Hofmann, the Breslau firm that produced the R I, was a manufacturer of locomotives? The bulky R I first flew in 1917, but problems quickly surfaced. Because the pilot sat 20 feet off the ground, he had a hard time judging distances during landings. Just weeks after its maiden flight, the first R I's wings collapsed and the airplane crashed. Another R I was built that year, but it too crash-landed and was never rebuilt.

John Batchelor notes: "To make it more difficult to see in the air, they covered the fuselage with clear material, prompting my nickname 'the Square Condom.' "

AYRES CORP.

Ayres Loadmaster
United States
Nominated by the staff of *Air & Space/Smithsonian*

As its name implies, the Loadmaster is primarily a cargo hauler, but Ayres foresees it serving as a regional airliner, troop transport, and reconnaissance/surveillance craft. A prototype is scheduled to fly next year, with deliveries to prime customer Federal Express the following year. The long snout beneath the squinty-eyed cockpit carries two turboshaft engines that drive the single propeller, and the pursed-lip air intake gives it the expression of someone undergoing a sigmoidoscopy. The Loadmaster is also available on floats.

Says Terry Humphrey of Ayres marketing and flight test: "What we hope is that someday pilots, operators, and stockholders will see our aircraft in the sky and say, 'Well, it may not be the prettiest aircraft in the world, but for a long-snouted, squinty-eyed, pursed-lip airplane, it sure does an excellent job.' "

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COMMENTARY:

Loss of Innocents

Only one day after Russian president Boris Yeltsin pledged to stop the air raids that were endangering civilians in the Chechnyan capital of Grozny late in 1994, Russian warplanes bombed and destroyed an orphanage there. Fortunately, the facility's 20 children had been playing in the basement at the time and survived the attack. Many children in war zones in recent years, however, have not been so lucky. According to a report by the British branch of the humanitarian group Save the Children, during the past 10 years, 1.5 million children have been killed in wars throughout the world.

Before we lose more children and adult noncombatants, the nations of the world must formulate and ratify an international law of air war convention. Such an agreement will not prevent all such deaths and it may not see all those who violate the agreement punished. But an air war convention would, I believe, reduce the number of civilian casualties. And it would clearly express the universal condemnation of the destruction of the Grozny orphanage and other atrocities.

Human beings not involved in combat have a historically recognized right not to be deliberately harmed by military operations and are currently protected in part by the 1949 Geneva Convention Relative to the Protection of Civilian Persons in Time of War. But although the airplane made its debut as an instrument of war more than 80 years ago, the world today has no specific set of laws to guide the conduct of air war. It's time that we did.

The strategic potential of air power seized the imaginations of many following World War I. In 1921, Italian general Guilio Douhet wrote that future aerial offensives would be directed against "industrial and commercial establishments, transportation systems, and designated areas inhabited by the civilian population." To justify the break with the laws of war that protect non-combatant civilians, Douhet argued that modern warfare involves a nation's total population. He concluded that "any distinction between belligerents and nonbelligerents is no longer admissible today either in fact or theory. Not in theory because when nations are at war, everyone takes part in it; the soldier loading shells in a factory, the farmer growing wheat, the scientist experimenting in his laboratory."

Douhet's theories had widespread influence in erasing the historical distinction between combatant and noncombatant. Along with the indiscriminate bombing of cities that had been practiced at times during World War I, his writings were also the impetus behind a comprehensive effort one year later to limit the use of aircraft as weapons: the 1922-1923 Hague Conference in the Netherlands.

The members of the commission—representing the United States, Great Britain, France, Italy, Japan, and the Netherlands—regarded the regulation of aerial bombardment as their most important issue. After considerable discussion, they adopted four articles on the subject, which, among other things, prohibited the use of aerial bombardment to terrorize civilians, declared aerial bombing legitimate only when directed at military objectives, specified what these targets could include, and specified others to be spared.

The conference ended on February 19, 1923. Although the United States' representative had indicated his government's willingness to accept the proposed rules, a twist of fate changed that course. Shortly after the U.S. Secretary of State received the commission's report, the U.S. Senate adjourned. Before

DAVID POVILAITIS

William H. Forman Jr. proposes a way to reduce civilian air war casualties.

the next Congressional session began, President Warren G. Harding died, and Calvin Coolidge, who favored a policy of isolation in the nation's relations with Europe, replaced him. When the Senate reconvened, it did not approve the proposed regulations.

Nor did three other governments that sent delegates to the conference. The Netherlands criticized the proposals for not adequately protecting neutral nations in time of war. France maintained that other existing international agreements already regulated air warfare adequately. Britain refused even to consider the proposed rules without further discussion, fearing that restraints on air power would cost it control over its colonial empire. The rules, therefore, were never adopted as an international treaty.

Nonetheless, in the early years of World War II, the combatant nations proclaimed that they wouldn't bomb civilians. Isolated but flagrant violations soon followed, however. And the uses of strategic bombing in later years of the war, the development and use of the atomic bomb, and the arms race of the cold war all transformed notions of precise military targets into fantasy.

The idea of protecting civilians from air warfare was dealt another blow at the Nuremberg trials, convened in Germany in 1945 to try German military and civilian officials charged with violating the Geneva conventions and other laws. During the trial of *Reichsmarshal* Hermann W. Göring, the prosecution raised the issue of the Luftwaffe's May 1940 bombing of civilians in Rotterdam, which killed 30,000 to 40,000 people. But the international military tribunal backed away from a determination of guilt on that charge, in good part because the Allies had used the same bombing methods. Although Göring was found guilty of crimes against peace, war crimes, and crimes against humanity, he—along with all the other defendants at Nuremberg—was not found guilty of crimes connected with the Luftwaffe's bombing operations.

The Nuremberg trials therefore became a key step in developing the body of the law of war that does not hold an airman criminally liable when civilians are killed in air attacks against military targets. U.S. Army Brigadier General Telford Taylor, chief counsel for the prosecution at Nuremberg, defined this presumption of lack of criminal intent as "a rule of reason." He wrote that due to technological factors, weather, and enemy resistance, an airman on a bombing mission was not able to discriminate between hitting a civilian and hitting a member of the armed forces.

The law of air war should be as advanced as the technology of air war.

Recent technological advances, however, have largely invalidated that assumption. Bombing is more than 100 times more accurate today than it was in World War II. Modern air forces measure bombing accuracy by determining the "circular error probable." The CEP is the radius of a circle within which half of the bombs are expected to land. According to U.S. Air Force historian Richard P. Hallion, the CEP for U.S. bombing during World War II was 3,300 feet. During the Persian Gulf war of 1991, the CEP of laser-guided smart bombs was about 10 feet.

The law of air war should be as advanced as the technology of air war. The Geneva conventions—although the first was written in 1864, the term usually refers to the four conventions completed in 1949—were part of an effort to prevent a recurrence of the type of atrocities the Nazis perpetrated and therefore emphasize the prevention of genocide, the protection of the wounded and medical personnel in wartime, and the improvement of the treatment of prisoners of war. They lack sufficient specific guidelines about what is and isn't a military target.

Ironically, we find that specificity in a document written long before the technology was invented that would enable nations to comply with its terms. A sophisticated effort for its day and time, the proposed Hague Convention of 1923 could serve as a starting point for a new international air war convention.

But we must go further. Aircraft and the conduct of air war have changed dramatically since the early 1920s, and we need a document to reflect that. We need to go still further, for example, in defining military targets. During the Gulf war, the Iraqi military used civilians as human shields to protect military enclaves from U.S. air raids. A new international air war convention could stipulate that such an arrangement still constitutes a military target and thus ideally discourage its use.

As the world's only remaining superpower, the United States must take a leadership role in protecting civilians from death from the air. This nation has led the world in air power during the first century of the air age. My hope is that it will continue to lead by codifying a law of air war before the century ends.

Formerly an Air Force judge advocate officer and a specialist in the law of war in the Air Force's international law division at the Pentagon, the author teaches international law at Tulane University in Louisiana.

Wright v.

O. & W. WRIGHT.
FLYING MACHINE.
APPLICATION FILED MAR 23, 1903

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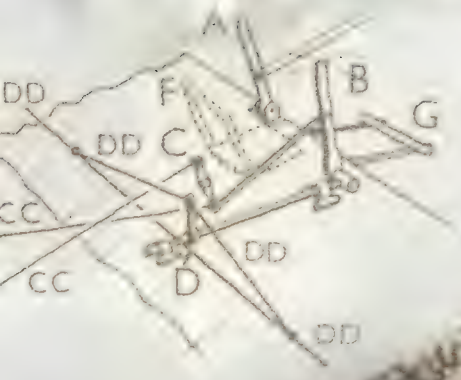
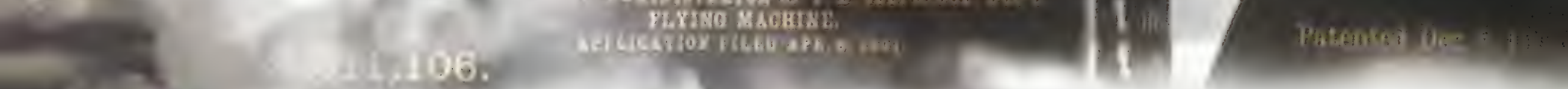
PETERS

Curtiss (CONT'D.)





In this landmark case, history determined what the courts could not. How would a jury decide today?

It was a feud that pitted the founding fathers of aviation against each other, and it left in its wake, according to one history, "a sordid trail of hatred, invective, and lies that muddy the pages of aeronautical history to this day."

Wright v. Curtiss became known as the Great Patent War, for the dispute centered on a patent Orville and Wilbur Wright had received in 1906 after making the world's first powered flight—a patent that had the potential to make the entire new field of aviation financially obligated to the Wrights.

The brothers' patent covered not just the *Flyer* they had built for their pioneering 1903 flight but the mechanisms they had designed to control the airplane's movements along any of its three axes. The portions of the patent that came to stir up the most controversy dealt with controlling roll—the rotation of the airplane along its longitudinal axis. The Wrights had devised a technique called wing-warping, in which the pilot exercised a system of cables and pulleys that simultaneously twisted one wingtip upward and the other downward. Wing-warping enabled the pilot to keep the wings level as they passed through eddies and currents of air, and also helped to turn the machine.

by Phil Scott

Illustrations by David Peters

Two years after the patent was issued, the next Americans took to the air: members of a small group of airplane builders in New York State called the Aerial Experiment Association, which included inventor Alexander Graham Bell and motorcycle racer Glenn Curtiss. The AEA had equipped its second airplane, *White Wing*, with control surfaces that were later christened "ailerons" (French for "little wings"). The ailerons were set at the rear of the wingtips and moved in opposite directions—that is, when one was raised, the other was lowered. In May 1908, Curtiss made the longest flights in *White Wing*: one 205 yards long, followed immediately by one of 134 yards.

Buoyed by their success, the AEA team continued to equip their aircraft with ailerons. A little over a year later, Curtiss found himself hauled into court by the Wrights.

The brothers argued that their patent was broad enough to include any mechanism that simultaneously presented opposite surfaces of the wingtips to the air. Ailerons, the Wrights contended, were just such a construction.

Wright v. Curtiss stretched over eight years; in the end, it was resolved not in court but in a New York City boardroom. Soon after America entered World War I, the principals took just two weeks to hash out a settlement. But the case's lack of a final courtroom decision raises questions: If the battle had been fought to a conclusion—or if it had been held in a court today—which party would have prevailed?

When the Wrights slapped Curtiss with a lawsuit, they were by no means singling him out—not at first, anyway. According to Marvin McFarland, the editor of *The Papers of Wilbur and Orville Wright*, "The Wrights had been convinced that ailerons infringed their patent on wing warping ever since such devices had first appeared in France several years earlier," on craft fashioned by such men as Robert Esnault-Peltérie and Alberto Santos-Dumont. Altogether, the Wrights eventually became entangled in about three dozen patent infringement suits.

After receiving their patent, the Wright brothers expected anyone selling or commercially flying anything that wasn't a Wright machine to fork over up to 20 percent of the machine's value. Airshow organizers too were ordered to pay up 20 percent of the total prize money and 10 percent of the grandstand and gate receipts (levied retroactively, if necessary). And the Wrights expected royalties from all over the world, for after they got a patent in the United States, they received similar protection in France, Italy, England, Austria, Hungary, Belgium, Germany, Russia, and Spain. "Here was an invention of huge importance, and here was a patent with broad claims covering every heavier-than-air craft ever flown, so it becomes a matter of there being incredible potential profit to be made," says Rod Worrel, a Fresno, California patent attorney who has studied the Wright patent extensively.

But just a few airplane manufacturers, including the Burgess Company of Massachusetts and the Glenn Martin Company of California, opted to pony up the steep royalty fees the Wrights charged. The others either ignored the brothers' demands or went out of business. Only Curtiss fought.

In the first round of *Wright v. Curtiss*, Judge John Raymond Hazel issued a temporary injunction that forbade Curtiss to manufacture any more airplanes. "[T]he claims of the patent in suit should be broadly construed," Hazel wrote, "and when given such construction the elements of the Wright machine are found in defendants' machine performing the same functional result. There are dissimilarities in defendants' structure...which may be improvements, but such dissimilarities seem to me to have no bearing upon the means adopted to preserve the equilibrium...."

Curtiss posted a $10,000 bond and appealed. In June 1910 the U.S. Circuit Court of Appeals overturned the injunction. Both sides dug in for a protracted battle.

The Curtiss team adopted a four-prong defense strategy, arguing, according to C.R. Roseberry's book *Glenn Curtiss: Pioneer of Flight*: "(1) That the Wright patent was not entitled to the broad interpretation. (2) That if it were to be broadly construed, it was invalid because of the prior art [i.e., before the Wrights, someone had already devised a way to accomplish essentially the same thing]. (3) That if it were properly construed as to its scope, the defendants did not infringe. (4) That in any event the Curtiss mode of flying was on a different principle."

In 1913 Judge Hazel made his final ruling: It was for the Wrights. Curtiss appealed again, but a year later the appellate court sustained the decision.

Curtiss wouldn't give up. To buy more time he installed a mechanism on his airplanes' wings that worked each aileron separately, instead of in conjunction. Though the Wrights' patent had covered that method of lateral control, it hadn't been mentioned in the first lawsuit, so the Wright Company was obliged to start all over, filing a new lawsuit. That enabled Curtiss to get a temporary stay of the injunction barring him from producing airplanes.

Meanwhile, he kept an eye out for an opportunity to prove "prior art"—that someone would have been able to achieve controlled flight before the Wrights. In 1914 the Smithsonian Institution provided just such an opportunity when it contracted to have Curtiss try to get the *Great Aerodrome* airborne. (Students of aviation history will recall that the *Aerodrome*, designed by Smithsonian Secretary Samuel P. Langley to be the first craft to achieve manned powered flight, had failed miserably in two 1903 attempts, both times plunging into the Potomac River.) Cur-

tiss rebuilt and substantially modified the *Aerodrome*, even refurbishing it as a floatplane. In May he managed to coax it off Lake Keuka in his hometown, Hammondsport, New York, for a few seconds. Later that year, a local pilot he had hired, Ellwood Doherty, was able to sustain flight in the *Aerodrome* for over half a mile.

But the flights proved unnecessary: In the end, *Wright v. Curtiss* was settled out of court. In 1917, a number of airplane companies came together to form the Manufacturers Aircraft Association, with the goal of maximizing the nation's wartime aircraft production. The group pooled all of the members' patents, which allowed everyone to manufacture whatever aircraft or part the U.S. government needed. Each time a manufacturer produced an aircraft or part, he would pay a flat fee to a pool. The patent holders were reimbursed from the pool according to the relative values of their patents. The Curtiss and Wright companies each received a total of $2 million. And thus the Great Patent War ended not in a victory but a cease-fire.

But what if the war had continued? Who would have won?

Rod Worrel maintains that the Wrights' patent covered more than just wing-warping. "The claims of the Wright patent were directed broadly to presenting air surfaces at the opposite ends of wings," he says. "The inventors didn't care how it was done—it could be accomplished by *any* surfaces creating an imbalance of lift at the opposite ends of the wings to maintain control." Indeed, the patent states explicitly: "We wish it to be understood, however, that our invention is not limited to this particular construction [the *Flyer*'s wing-warping control], since any construction whereby the angular relations of the lateral margins of the aeroplanes [wings] may be varied in opposite directions with respect to the normal planes of said aeroplanes comes within the scope of our invention."

But weren't Curtiss' ailerons such a vast improvement over the Wrights' wing-warping that they constituted another invention altogether?

"The second inventor is entitled to a patent on his or her improvement if the invention otherwise meets the standards of the patent laws," says Worrel, who adds that meeting those standards requires satisfying three main criteria. First, the invention must be patentable subject matter: You can't patent the general idea of stable flight, for instance, but you can patent a structure to keep a flying machine stable. Second, the invention has to be new; it cannot be something previously known, whether patented or not. And third, the invention must not be "obvious"—it can't be something that would have been considered obvious to someone "skilled in the art."

The U.S. Patent Office must have decided that the Aerial Experiment Association's aileron design met these criteria, for it awarded the group a patent for the mechanism in 1911. (Though several French inventors had come up with versions of ailerons earlier, apparently no one at the U.S. Patent Office had been aware of them.)

"Glenn Curtiss certainly contributed an improvement to the art," says Worrel, so the inventor was entitled to a patent on his invention and to royalties from anyone who used it. At the same time, as long as Curtiss continued to make, use, or sell airplanes covered by the Wright patent, he would still owe the Wrights royalties during the 17-year life of their patent. "This is certainly equitable," maintains Worrel, "because Curtiss' improvement would not have been possible without the Wrights' prior invention."

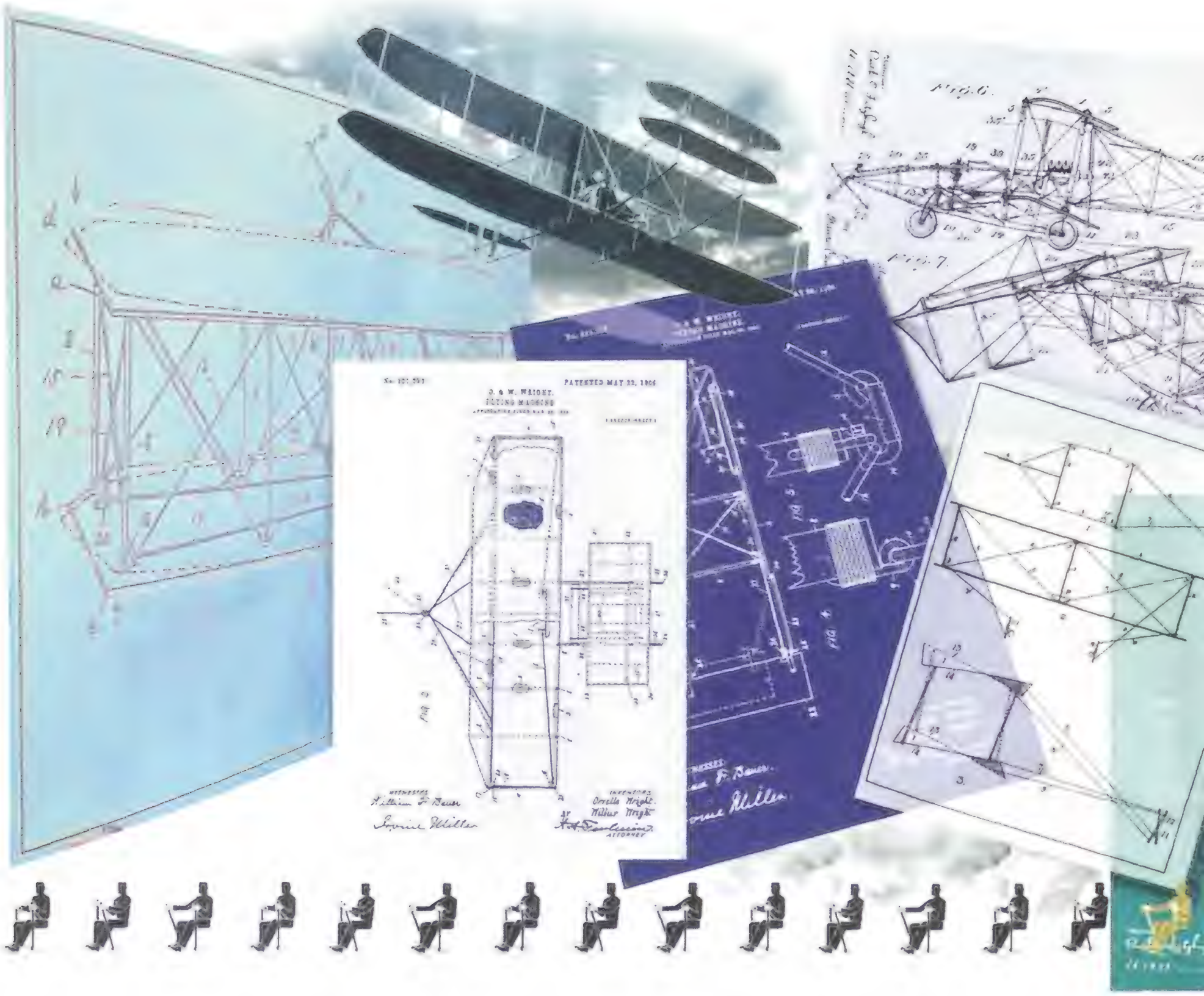
Had Curtiss kept the suit alive and lost, he would have had to pay royalties retroactively, even if the Wrights' patent had by that time expired.

With the risks so high, why did Curtiss continue to fight?

In a letter to his friend Washington Irving Chambers, a Navy aviation engineer, the inventor wrote that he was defending not just his own interests but those of the entire burgeoning field of aviation: "Had we not taken this stand, the Wright Co. would have been in position to enjoin all manufacturers and the whole industry would have been monopolized...." At the time, Worrel explains, President Theodore Roosevelt's trust-busting campaigns and new anti-trust laws had caused some courts to put more emphasis on anti-trust issues and less on patent issues. Because of the prevailing legal climate, Curtiss may have hoped that the court would give the Wright patent only a narrow interpretation. The broad reading the patent ultimately received appeared to have caught Curtiss by surprise, but Worrel, for one, feels that the interpretation was justified by the significance of the brothers' invention.

Would a patent as broad as the Wrights' hold up in court now? Probably, but for unexpected reasons. *Wright v. Curtiss* wasn't a jury trial, points out Donald Chisum, a University of Washington law professor who has authored a nine-volume reference on patent law; these days, he says, "we try so many patent cases before juries, which they didn't do then. The thinking is that juries are prone to favor inventors."

Still, had the conflict erupted today, Curtiss could have tried an approach

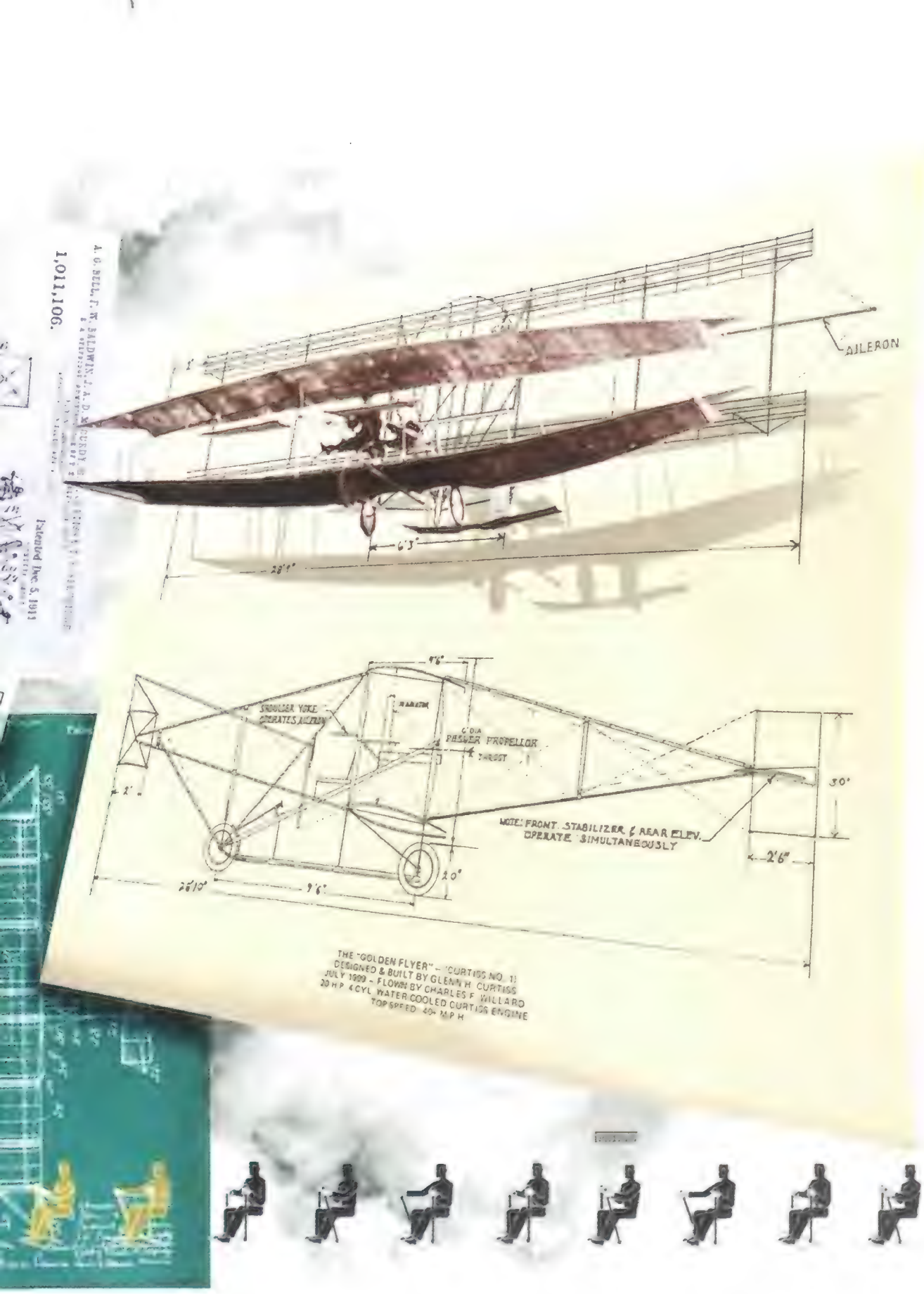


not available in his day. Patent applicants are required to cite references to publications describing similar work; if someone can make a case that an application omitted pertinent citations, he can petition to have the application reexamined.

Wright defenders think the brothers made no such omissions—that their ideas were genuinely original. And yet almost from the start, the story of the Wrights has been plagued by a counternarrative of doubt—a resentful belief that others had been capable of flight before the Wrights, or at least had beaten them to the idea of wing-warping. Perhaps the brothers' litigiousness fed the skepticism. Commenting on the Wrights' first suit against Curtiss, fellow aeronautical pioneer Octave Chanute confided in a letter to a friend, "Not only will this antagonize very many persons but it may disclose some prior patents which will invalidate their more important claims." Chanute elaborated in another letter: "The bare idea of warping and twisting the wings is old.... Pettigrew in *Aerial Locomotion* laid great stress upon its importance. I think Count d'Esterno took out a patent in France (somewhere about 1860) for one method, and Le Bris, about the same time, for another...." (Needless to say, the Wrights disagreed vigorously that these inventions accomplished what theirs did.)

And the brothers' suit against Curtiss had another unhappy effect: According to Marvin McFarland, the editor of the Wrights' correspondence, the lawsuits, coupled with the brothers' formation of the Wright Company, "were interpreted to mean that the Wrights were laying aside, at least temporarily, their mantle as scientists (in which few of their contemporaries, especially those with professional training, were willing to see them cloaked), and were assuming the role of active businessmen...." The perception was exemplified by a remonstration Chanute made in a letter to Wilbur Wright: "I am afraid, my friend, that your usually sound judgment has been warped by the desire for great wealth."

In addition, the Wrights' lawuits are commonly blamed for stifling aeronautical advances in the United States.



One person who held this view was Tony Doherty, whose father, Ellwood, had worked for Curtiss as a pilot on some of the 1914 *Great Aerodrome* flights. "In Hammondsport the oldtimers used to say if you jumped up in the air and flapped your arms you'd be infringing on the Wrights' patent," recalled Doherty, who died last year at age 79. "It held back the development of American aviation, as you well know. Service pilots who came to Hammondsport to fly were irritated and irate because there was so much lack of development."

That ubiquitous belief is starting to be challenged. Wright biographer Tom Crouch of the National Air and Space Museum has been researching the issue, and he argues that blaming the brothers "masks the real reasons that the United States fell behind Europe during the years prior to World War I. European investment in aeronautics—in every area from research and development to direct aircraft purchases—was much higher than in America."

For his part, Orville Wright insisted that his company's demand for royalties was actually "an act of great benefit to aerial navigation.... What incentive was there to do hard thinking when anyone could loot the thinking that had previously been done?

"I want all the inventors who can possibly be brought into the industry to work upon the aeroplane," he continued. "And let them start with the problem of bringing in something new—beyond the scope of our patents, which will render the patents useless and obsolete. Then we will be glad to retire in their favor."

As it happened, the Wrights' involvement in aviation did end soon after, though not under happy circumstances. Wilbur died in 1912, and three years later Orville sold the business, leaving the lawsuits for the new owners to slog through. As talented as he was, Orville spent much of the rest of his life not designing aircraft but rather defending the Wrights' place in history—corresponding with anyone who had questions, attempting to get his views across by sitting with newspaperman Fred Kelly for a sympathetic biography, *The Wright Brothers*.

The Wright Company languished and eventually stopped building flying machines, while Curtiss Aeroplane and Motor Corporation went on to mass-produce some of the most famous airplanes in history. World War I brought lucrative military contracts to build such aircraft as the Curtiss Jenny trainer and the enormous NC flying boats. When the two companies ironically merged in 1929 to become Curtiss-Wright, it was to one's satisfaction and the other's disgust that the name Curtiss came first.

But as it turns out, the Wrights may yet get the last word. Wing-warping may be making something of a comeback. Engineers at the appropriately named Wright Laboratory of the Wright-Patterson Air Force Base in Dayton, Ohio, have been working on a new twist to the old method. It's based on a phenomenon called aeroelasticity, in which aerodynamic forces act on elastic structures. Engineers have discovered that wings given a measure of elasticity can be controlled much more economically and powerfully than conventional wings with ailerons. Northrop Grumman is presently testing the concept on F/A-18 wings (see "Air and Space Futures: Smart Wings," Apr./May 1996), and the Wright team hopes to employ it on the next generation of high-speed fighters by the year 2000 or 2001—nearly 100 years after the Wright brothers first lifted off the sandy dunes of Kitty Hawk. But before tests begin, the team would do well to find itself a good patent lawyer.

The Edwards Diaries

Test pilot Glen Edwards kept book on the Flying Wing. Now we know what he thought of the airplane he died in.

EDWARDS AFB HISTORY OFFICE

The Northrop YB-49 Flying Wing was the most futuristic airplane Captain Glen Edwards (inset) had ever flown.

by Daniel Ford

Photographs by Roy Wolford/Northrop

John K. Northrop and Glen Edwards never met, but their paths nearly crossed in February 1946, at Wright Field in Dayton, Ohio. Captain Edwards, a 50-mission veteran of World War II, had earned a coveted slot as an Army Air Forces test pilot. But this was the peacetime Army, with low pay, slow promotion, and, for test pilots, a death rate rivalling that in wartime. When Northrop visited Wright Field to discuss his B-35 Flying Wing bomber, Edwards got wind of it: "Mr. Northrop is here today," he wrote in his diary on February 20. "Hope to talk to him tomorrow concerning employment.... If such is possible, [I] do believe I'd leave the Army." But before Edwards could finagle an interview Northrop was gone. "Blast the luck," Edwards wrote the next day.

The Army would also need pilots for the XB-35 acceptance tests, and in March, the Bomber Test Branch sent Edwards to California's Muroc Army Air Base, a place of scorching loneliness. He was one of several test pilots—Robert Cardenas and Daniel Forbes were others—to qualify in the N-9M, a pint-size version of the big bomber. "The first takeoff is an experience not soon to be forgotten," he reported to the Air Technical Service Command. "The plane comes off the ground of its own accord between 70 and 75 mph and immediately assumes a steep nose-high attitude." Its directional stability was poor, and when turbulence disturbed it, the little Wing would take four or five oscillations before Edwards could return to the compass heading. He stalled the Wing once ("with great caution") and it recovered normally. "The plane flew surprisingly well," he concluded. "...far better than most would expect."

But in his diary he expressed more skepticism. "Boy, that was quite an experience," he wrote that evening. "Quite different from flying anything else. It would take a good bit of practice to get really good at flying the little beauty."

Most of Jack Northrop's airplanes were beauties. He believed that "if something is efficient and beautiful, it is *right*." During stints at Douglas and Lockheed, he was always dreaming of aircraft sleeker and more efficient than the conventional craft the manufacturers had to build in order to survive. Early on, he met a Czech-born barnstormer and shop foreman named Anthony Stadlman, who told him about tail-less, swept-wing aircraft that had been flown in Europe. From about 1919 until 1927 the two men worked together at Lockheed (when it was spelled "Loughead"), then Douglas, then Lockheed again, and in their spare time they actually built an all-wing glider. Sometime toward the end of

NORTHROP (2)

this period a rift developed between them, and Stadlman would later claim that a model flying wing he had built and shown to Northrop was the basis for Northrop's subsequent designs. Their parting was bitter.

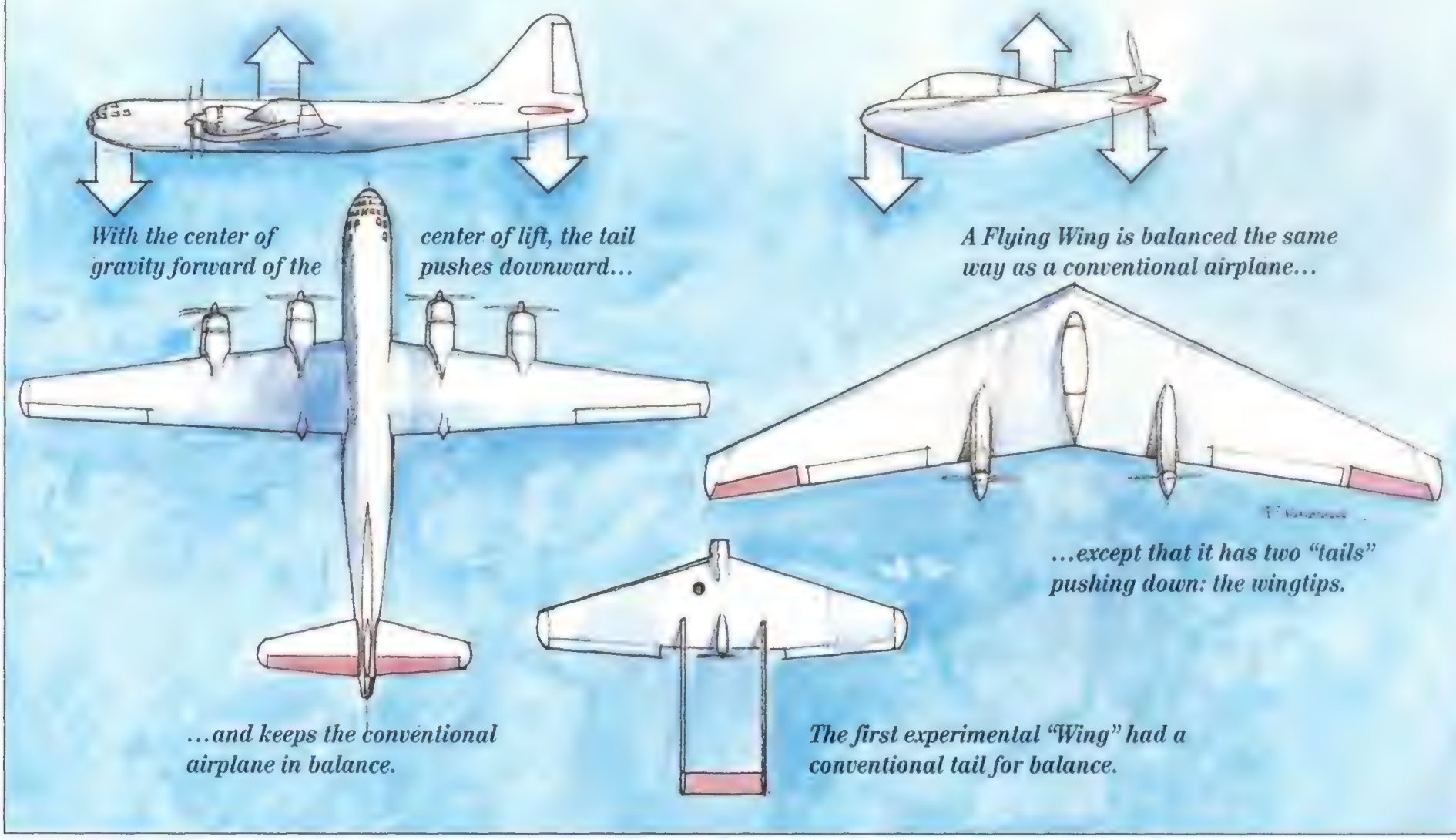
Northrop produced his first attempt at a powered flying wing in 1928. His Experimental No. 1, which does look suspiciously like the one Stadlman is holding in an old photograph, flew in 1929. Northrop financed the project with profits from the Vega, a sleek, high-wing, conventional airplane he had designed during his second stint with Lockheed.

In September 1939, just as Germany invaded Poland, Northrop opened his own plant. It was superlative timing, and he soon had orders from Norway and Britain as well as Boeing and Consolidated. His vision, though, was still bent on the perfect airplane, the Flying Wing. He retained Theodor von Kármán, who taught aerodynamics at the California Institute of Technology and who recruited one of his brightest students, William Sears. They worked like this: Northrop sketched a Flying Wing, von Kármán wrote long equations on the blackboard, and Sears inked their thoughts on paper.

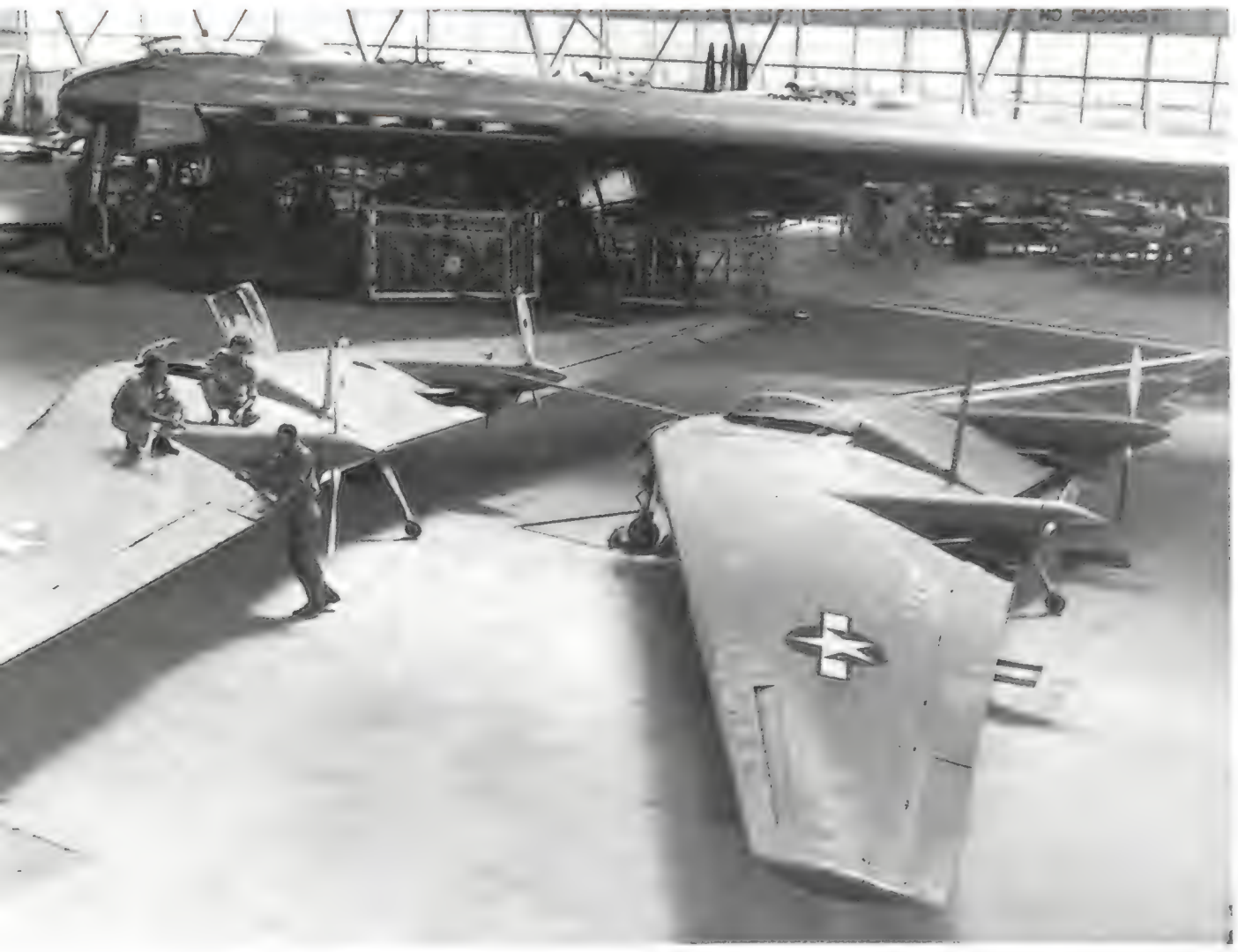
The airplane Sears drew became the N-1M, for Northrop

Northrop's experimental 1929 model had a conventional tail (left), but the N-9M (below) was a true flying wing and the first tailless airplane Edwards (in khakis) was exposed to.

How a Flying Wing Keeps Its Balance



FRANK KUCZAK



A working test bed, the N-1M had adjustable wingtips, but the droop seen here didn't work; maximum sweep did (top). The young John Northrop (right, standing) saw a true flying wing as the aerodynamic ideal. Above: Workers tend two of four N-9Ms in which Glen Edwards and others trained.

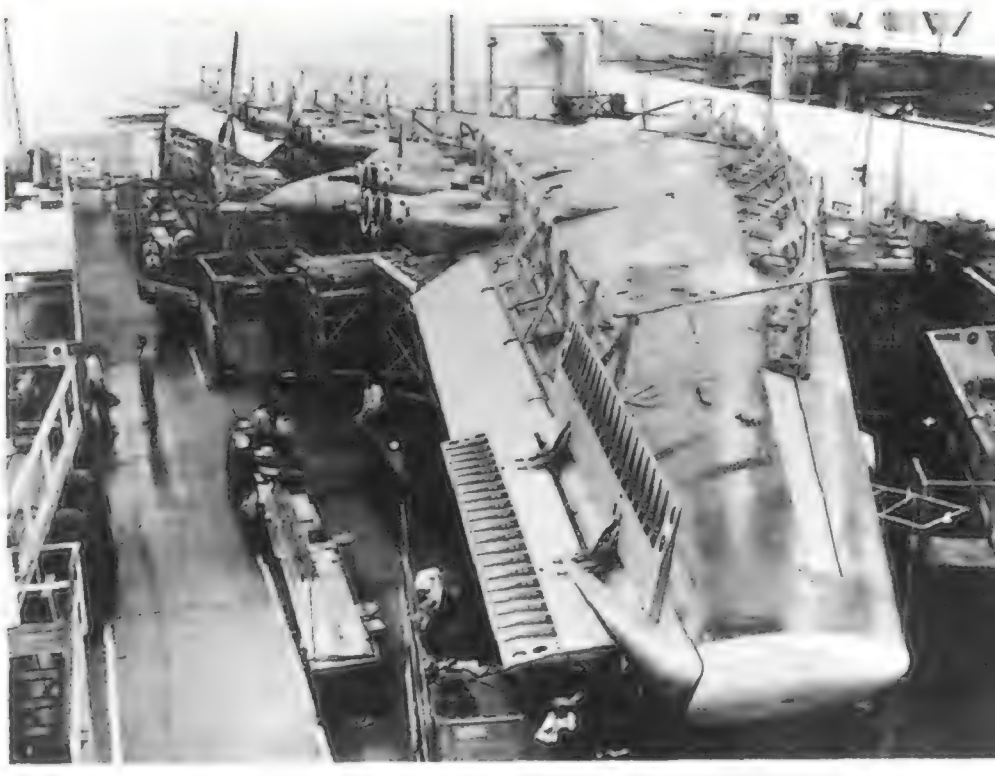
First Mockup. It was a true Flying Wing, with all its control surfaces—including rudders—in the trailing edge. It was underpowered, though, and on its maiden flight in July 1940, it couldn't climb out of "ground effect" and simply flew along at low altitude, gaining lift from the cushion of air between its wing and the ground. "It looks like we have an airplane with a 20-foot ceiling," Northrop said, watching the pretty craft skim the Muroc lake bed.

With an improved airfoil and bigger engines, the N-1M finally got up to a respectable altitude. Its best feature was that its wingtips were adjustable, and both the droop and the sweep of the wing could be modified between flights. The winning configuration proved to be a straight wing, one without any droop at the tips and with the sweep set back as far as it would go. Sweep, it seemed, was the key to tail-less flight: Positioned behind the geometric center of the wing's lift, the wingtips became tails. (The restored N-1M Wing can be seen at the National Air and Space Museum's Garber Facility in Suitland, Maryland, although without the inserts that increased the wing's sweep, which was the N-1M's most significant contribution.)

By 1941 German troops occupied most of Europe's capitals and appeared ready to capture London and Moscow next. Fearing it might have to fight a transatlantic war, the U.S. Army wanted a super-bomber that could carry 10,000 pounds of bombs to Germany from North America. Northrop built the B-35, a Flying Wing, while Consolidated Aircraft developed the B-36, conventional in every respect but its size (see "B-36: Bomber at the Crossroads," Apr./May 1996).

Even the Wing was huge by the standards of the day: It spanned 172 feet, weighed 100 tons, and developed 12,000 horsepower from four huge engines. It was such a giant leap from the N-1M that the Army also agreed to fund an intermediate version. One-third the size of the big bomber, the N-9M was supposed to be aerodynamically identical. So it

JACK QUINN / USAF



The trouble-plagued XB-35 (top), shown with a P-61 Black Widow flying chase, may have helped morale on Northrop family days (above), but its propulsion systems kept it mainly on the ground. Exhaust stains reveal the location of its enormous Pratt & Whitney R-4360 engines near the wing's leading edge (opposite, top), and it was a long reach for a vibration-prone shaft to the horrific gearboxes for the four contra-rotating propellers aft of the trailing edge. Its engines overheated and its propeller governors were faulty; most of its troubles were due to government-supplied parts. The sheer complexity of the Flying Wing was thought to be more than its crew could handle, as evidenced by the YB-49's flight engineer's station (opposite, bottom). But the airplane established at least one basic concept that survives in the B-2: rudders consisting of "clamshell" surfaces near the wingtip that split to exert drag and produce yaw (above, right).

was a bad omen when the first one was delivered late, cost more than budgeted, rattled and shook, failed to deliver the promised range, and then crashed, killing its pilot.

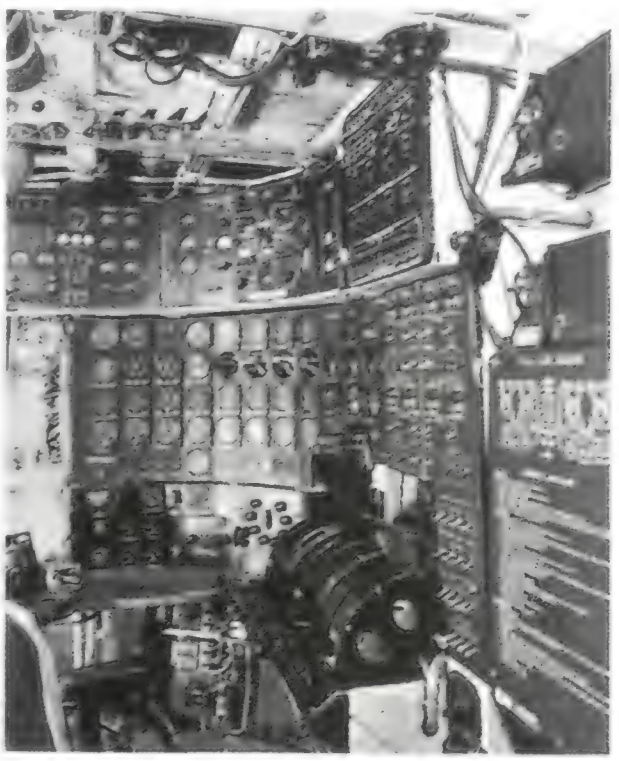
Lacking a fuselage and tail, a Flying Wing can rotate easily around its lateral axis—the imaginary line running spanwise through the wings—and even Jack Northrop fretted that his design might be inherently unstable. While he was experimenting with moving the N-9M's center of gravity forward and aft, the test pilot apparently let the nose point so high that the wing stalled.

Now, if you stall a Cessna, you can release back pressure on the control stick and the airplane will drop its nose naturally and resume flying. A Flying Wing is not so polite. In the N-9M and other all-wing aircraft of the time, the airflow separation at the stall rendered the trailing-edge control surfaces ineffective (see "Go With the Flow," June/July 1995). Or worse, the forces on the controls reversed, slamming the control stick into the pilot. The Wing might go into a tail slide, flip over backwards, or fall off to one side in a spin.

In time, the team of Northrop, von Kármán, and Sears tamed the N-9M, but the Army was losing patience with the development problems at Northrop and Consolidated. Development of the B-36 was behind schedule, and the XB-35, which was even more of an engineering challenge, had yet to fly. So the production contract was canceled, leaving only two X (experimental) and 13 Y (service test) B-35s on order.

The XB-35 finally took to the air in June 1946, almost a year after Japan had surrendered. Company pilot Max Stanley flew it to Muroc Army Air Base. "No trouble," he reported. The same couldn't be said of the XB-35 thereafter: Its engines overheated, its propeller shafts vibrated, its propeller gearbox broke down, and its auxiliary power unit (a gasoline-powered electrical generator) failed. In the end, the X models would manage to fly for a total of 36 hours, for an amortized cost of $1.8 million per hour.

It didn't matter, because the Army had already decided to adapt its superbombers to jet propulsion. Consolidated (now called Convair) would hang four turbojets on its B-36, outboard of its piston engines. Northrop's Flying Wing would get an even more radical makeover, its engines replaced by eight turbojets, along with a new designation: theB-49. Because the airframe had proved airworthy, it could go straight into flight test, and with little delay: The first YB-49 was rolled out in October 1947. "Spewing a twin trail of black smoke, the sky monster swept into the air before the awed thousands gathered to witness the historic take-off," gushed a company press release. Max Stanley was again at the controls, and again it was a delivery flight to Muroc—now the property of the newly independent United States Air Force.



In theory, company pilots performed the initial flight tests on new airplanes to prove their airworthiness, then military pilots put them through acceptance tests. In fact, the Air Force's Bomber Test Branch was involved from the first day. When the second YB-49 was ready, Major Robert Cardenas flew it from the factory to Muroc. Cardenas was also the pilot on February 23, 1948, when the nosewheel door blew off the "Two" (the test pilots coined a shorthand to refer to the first two airplanes—the One and the Two). With jet engines, the Wing simply took off too fast. Thereafter, Cardenas lifted the nose as soon as the wheels left the ground, bleeding off speed until the wheels retracted. "Then you leveled off," he recalls, "and you'd sit there rocking in your seat, back and forth, in unison with the slosh of the fuel." The B-49 had no fuel-cell baffles.

Perhaps more serious, the turbojet lacked the stabilizing effect of the B-35's propellers and prop-shaft fairings. To compensate, the airplane had been equipped with four tall vertical fins, which were carried forward as "fences" to prevent the air from flowing toward the wingtips, a tendency that marred the performance of early swept-wing aircraft. So in some respects, the YB-49 really was a new airplane and could not be counted upon to behave exactly like the XB-35, never mind the relatively docile N-9M.

On April 26, a Northrop crew kept the Two aloft for nine and a half hours, and the flight set a record for jet endurance at altitude, though they had to shut down one engine, and the electrical generator failed. Nobody seemed concerned that the distance was only 3,500 miles—not much better than hundreds of Boeing B-29s had done in the Pacific. Even more astonishing, the old B-29 could carry a larger bomb load, including the large and heavy atomic bomb. Rarely mentioned in the Flying

Why a Flying Wing?

John Northrop's dream was to build the most efficient airplane possible, and in ideal terms, that means a design producing maximum lift with minimum drag. All designers strive to get as much as they can out of every pound of airplane, but all airplanes must be controllable, and traditionally, stability in pitch—the axis that controls climbing or descending—is provided by tail surfaces that balance the airplane. The tail is there to provide a balancing down force to keep the airplane level. Without its tail, a conventional airplane noses down. But Northrop saw these separate surfaces as excess weight and drag.

In the act of creating lift, the wing itself produces *induced drag*. The wing creates a downwash as it passes through the air. As a result, the force of a wing's lift is tilted slightly aft, so the force of lift has a significant component force that acts against thrust; this is perhaps the simplest way to describe induced drag.

Wheels and struts poking into the airflow—any parts of the airplane that contribute nothing toward lifting it—create *parasite drag*. Retractable gear was developed to reduce parasite drag. Other forms of drag include *interference drag*, produced at junctions between the parts of the airplane, *form drag*, created by the shapes of the parts, and *skin friction drag*, which varies with the total surface area of the airplane and represents the friction of air flowing over it. Even the balancing force of the traditional tail pushing down creates a component of the airplane's total drag.

Northrop saw in the all-wing aircraft a purity of form in which every pound and every square inch was working for the cause.

Wing saga is the fact that the YB-49 bomb bays were too small for "Fat Man," the plutonium bomb dropped on Nagasaki and still the U.S. standard in 1948.

Shortly after this modest success, the Air Force sent Cardenas to the University of Southern California to get an engineering degree. Back at Wright Field, Glen Edwards wrote in his diary: "Then this evening all heck broke loose. Seems like I'm bound for Muroc tomorrow by fastest means possible. Plan to run stability [tests] on the YB-49...what fun! Sounds like I'll be there for awhile. Packing like mad tonight."

The Air Force had two series of acceptance tests, one for performance measures like speed, altitude, and rate of climb, the other for stability and control—the qualities that make an airplane either easy, comfortable, and safe to fly or tiring, uncomfortable, and risky. Accordingly, the two YB-49s each had a different set of instruments. The first was meant to test stability and control; this was Glen Edwards' specialty, so the One would be assigned to him.

After a hectic flight to Muroc with an Air Force civilian engineer named Charles LaFountain, Edwards met the One on Thursday, May 20. As his check-out pilot, Cardenas occupied the raised pilot's seat under a bubble canopy that was bolted in place. Edwards was in the copilot's seat, at deck level, looking through plexiglass panels in the leading edge

of the wing—a view so restricted that he could neither take off nor land. The next day they changed seats. "I flew the airplane," Edwards noted in his diary, "and must confess it is somewhat of an experience. Stability is poor all around—landing is peculiar. Has a great tendency to float." (That was ground effect, especially pronounced on an all-wing aircraft.)

Cardenas left Muroc that Friday. Though Danny Forbes outranked him, Edwards was the more experienced and better-trained test pilot, so he was given overall command of the YB-49 program. It was slow going.

"Got two flights off today with doubtful success," he wrote on the following Thursday. "Darnedest airplane I ever tried to do anything with. Quite uncontrollable at times. Hope to be more favorably impressed as time goes on."

That day, Northrop formally turned the Two over to the Air Force. This was the YB-49 equipped to measure performance, and it would be commanded by Danny Forbes. The two men flew seven hours that day. When they flew the Two, Forbes was aircraft commander and Edwards his copilot; in the One, they swapped seats and responsibilities.

After the new YB-49 departed Hawthorne, California, before neighborhood crowds (above and opposite, below) to begin tests, system failures continued to plague it. The conversion to eight turbojets, four to a side (opposite, top), solved some of the propulsion problems but produced others. Without the stabilizing effect of propellers, the craft needed four vertical surfaces. But what seems most evident today from these views is the thickness of its airfoil, which was ill-suited to jet speeds.

First a rainstorm drenched Muroc Dry Lake and put a halt to the program. Then Colonel Albert Boyd, the famously ferocious chief of the Flight Test Division, turned up with a contingent from Wright Field. What with one thing and another, it was Thursday, June 3, before they were able to resume the original pace. "What a wonderful day this has been!" Edwards wrote that evening, in what would be the last entry in his diary. "Got off two flights on the YB-49, a lovely flight on the DC-6, one on the C-74—and I'm bushed!... Col. Boyd flew the YB-49 for the first time today and wasn't too impressed. We all share the same views. A passable airplane in ideal conditions."

Edwards had flown the One in various configurations for nearly four hours that Thursday, stalling it with the landing gear down, with the landing gear up, and with flaps at all possible settings. Then Boyd flew it for another hour, after which the airplane was turned back to the manufacturer for a new round of tests. As Gary Pape summarized these tests in his book, *Northrop Flying Wings*, they were to probe "stability, control, and stalling characteristics that the AF pilots...felt were unacceptable."

On Friday, therefore, Edwards was back in the right seat as copilot in the Two. Over the course of four hours, Forbes and he made a high-power climb, ran speed-power tests at 10,000 feet, and calibrated the airspeed indicator. Then the two pilots telephoned Colonel Richard Horner in Dayton. Both pilots complained about the data they'd collected on aileron response, though it isn't clear whether they were finding fault with the airplane or alluding to trouble with the data collection systems. In any case, both the Dayton and Muroc contingents agreed to make an extra flight next day with "an augmented crew of test engineers."

So at 6:44 a.m. on Saturday, June 5, the Two took off on its final flight. Forbes was in the left seat, as aircraft commander, with Edwards flying as copilot on the right. Lieutenant Edward Swindell, who had the crucial task of balancing the airplane by feeding fuel to the engine from tanks that were forward and aft of the center of gravity, was behind them in the rear-facing flight engineer's seat. Two civilian engineers, Claire Leser and Chuck LaFountain, made up the "augmented crew."

Because it was Saturday, no chase plane was available, so the only first-hand reports came from Forbes himself. Just after 7 a.m., he radioed that he was over Bakersfield and climbing; half an hour later, that he was "over north end of Antelope Valley, 15,000 feet, and descending." As Northrop test pilot Fred Bretcher recalled the mission, it should have involved a climb to 40,000 feet and a series of performance tests—too many tests for Forbes and Edwards to have completed in 30 minutes. Probably the auxiliary power unit had pooped out before the Two reached its service ceiling, so Forbes had returned to an altitude where the APU could generate the power he needed to operate the electrical systems.

Their next chore was a series of stall tests at 15,000 feet, where the air was smoother. According to technical files from this series of tests that are preserved in the National Air and Space Museum archives, an Air Force civilian, Robert Coleman, said that the plan for this flight was to keep increasing engine power and angle of attack as the tests proceeded. "If the airplane proved to handle cleanly during [low-power] stalls," Coleman recalled, "stalls with higher power settings were to be obtained.... It is known," he added, "that

Nine YB-35 airframes were converted to jet power (right). Three of four N-9Ms built posed in a rare formation (below). Only the fourth still flies (opposite), serving the Planes of Fame Museum in Chino, California.

the pilot was reluctant to attempt the higher power stalls."

If Forbes was reluctant, he had reason. In addition to repeated stalls as copilot to Edwards, he'd had a terrifying experience in February with Major Cardenas. That particular flight, Cardenas recalls, "resulted in a gyration that was abnormal. And I wouldn't stall the airplane again. Forbes knew that." In *Test Flying at Old Wright Field*, Cardenas gave more details: After stalling the One, he found himself at the controls of an airplane that was pointing almost straight up; refusing to respond to the controls, it was falling tail-first at 5,000 feet per minute. "The aircraft then tumbled over backwards," he wrote. After landing, he urged that no one perform intentional stalls in the YB-49. Forbes, he added, "heartily agreed" with that recommendation.

Wind tunnel tests had predicted just such a possibility, but Jack Northrop had dismissed it. "A vertical tail slide is hardly a maneuver to be courted [in] a 100-ton bomber," he'd told the Royal Aeronautical Society in 1947.

True enough, but a test pilot does what a test pilot must do. Forbes probably experienced his second and last tail slide on June 5, after which the YB-49 went over backwards or sideways into a high-speed, perhaps supersonic spin. Its outer wings tore off, probably when Forbes tried to level out and regain control. At some point the airplane exceeded its structural limit, later calculated to be 4.8 times the force of gravity. At 7:30 a.m., Major Russell Schleeh happened to be driving along the highway north of Muroc Dry Lake. A flash caught his eye—sunlight on aluminum—and he saw the Wing tumbling in at least two pieces. They crashed into the desert northwest of Muroc, the outer panels three miles from the crew compartment, which was consumed by fire.

The crash killed the Wing, as surely as it killed the men on board. After a company pilot showed that the One could indeed be stalled safely—at high altitudes—the Air Force took it back for bombing trials that did not help its cause. The airplane was not a steady platform and needed about four minutes to stabilize into straight-and-level flight. And with the bomb bay doors open, air turbulence tossed the bombs around as they were released. The airplane's supporters pointed out that its faults were easy to remedy.

In January 1949 Cardenas took the YB-49 on a high-speed exhibition run to Washington, D.C. It was also used in a secret project that may have involved its stealth capabilities, which Max Stanley had noticed while flying over an air defense radar station near San Francisco. The radar operators couldn't see the YB-49 until they stepped outside and looked with their own eyes.

Whatever it was about, the project never went anywhere, and the Air Force just wasn't interested in stealth—not then. The gargantuan B-36 carried a bigger load over twice the distance and flew so high that enemy fighters couldn't touch it. The Wing was a medium bomber, in some respects inferior to the B-29 of World War II and no match at all for Boeing's swept-wing B-47 Stratofortress. On the day the Air Force sent its new jets to Washington to impress the politicians there, Russ Schleeh crossed the continent at 603 mph in an XB-47, compared with the 511 mph Cardenas achieved flying the YB-49.

Nor could the gap ever be closed. "Northrop had insisted that the crew, fuel, and everything else had to go into the Wing," explained Theodor von Kármán in *The Wind and Beyond*, his 1967 autobiography. "This load made the Wing thick," with the result that at high speeds the airflow separated and "the plane began to shake and lose stability." Boeing's jet bomber could fly faster, higher, and almost as far—and it could carry Fat Man. "The B-49 had gear problems," Cardenas says. "It had engine problems, it had fuel cell problems, it had all kinds of problems.... It was not an operational bird. The cockpit layout was miserable. The crew could not escape if anything happened."

For more about the Flying Wing, visit the Web at www.airspacemag.com/supp/JJ97/Wing.html

PHILIP MAKANNA

The Air Force had begun to name its bases after Air Force heroes, favoring native sons where possible. The name of Glen Edwards—reared in Lincoln, California—was attached to the lonely facility in the Mojave Desert, which in time became the home of the Air Force's Flight Test Center. Muroc is now known to all the world as "Edwards," an icon so familiar that one word is enough to identify it.

In 1952, broken by the failure of his beloved Wing, Jack Northrop turned his company over to new management under Oliver Echols, a retired Air Force general. The firm prospered during the cold war, and in time it produced the ultimate cold war weapon: the B-2 stealth bomber, of which only 20 are to be built. Because the B-2 has no tail, comes from Northrop, and spans 172 feet, it's sometimes described as a modern B-49—and Jack Northrop's vindication. But even Northrop engineers have said that its shape evolved from stealth research—they started with a clean sheet of paper (see "The Invisible Men," Apr./May 1997).

The B-2 is flown by computers, not by its crew. Jack Northrop built his Flying Wing a generation before there was a proper means to control it, and the design was pushed beyond its capabilities. It couldn't carry an atomic bomb, nor could it reach targets in the Soviet Union—and if it had, it probably would have missed.

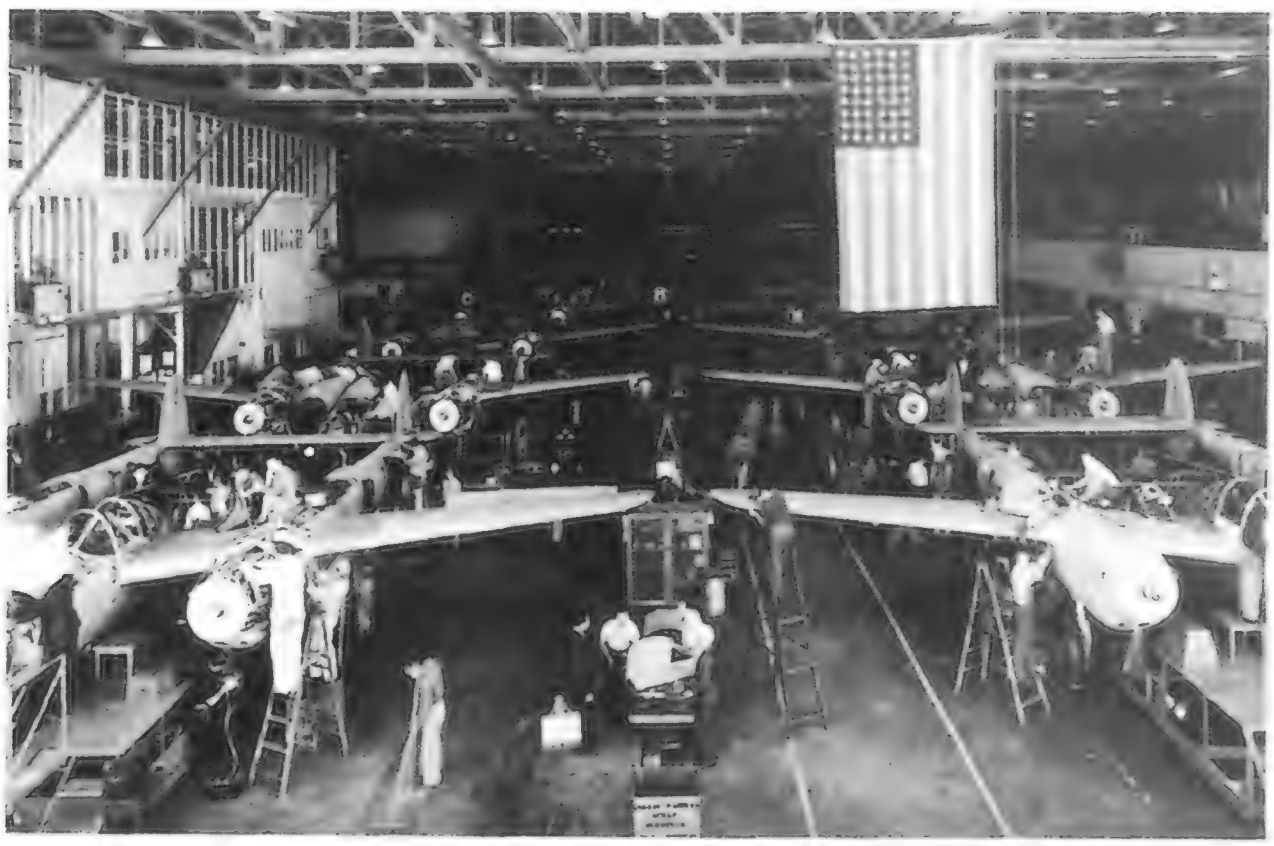
PETER MENZEL (3)

>SIGHTINGS<

"California's Lompoc Valley, where half the world's commercial flower seeds are grown, is at certain times of the year an incredible visual and olfactory experience," says photographer Peter Menzel of the pictures left and below. For the photo above, he explains, "I climbed into the hopper in front of the pilot wearing only a crash helmet and bathing suit. Standing knee-deep in 220 pounds of milk powder and water we mixed up to resemble the chemicals he had been spraying, I braced my elbows against the windscreen and shot cropduster Harley Mansfield with a fisheye lens while he sprayed a field at 100 mph, never more than 50 feet off the ground.

"That night, while having a drink with Harley, I learned why he was missing an ear. He had blacked out years earlier while cropdusting after loading his own chemicals and had awakened in his wrecked plane under snagged power lines in a cotton field. After that he never loaded chemicals himself."

Growth Industry



NASM

America's Hundred Thousand: The U.S. Production Fighter Aircraft of World War II *by Francis H. Dean. Schiffer, 1997. 606 pp. (large format), diagrams and b&w photos, $59.95 (hardcover).*

This isn't a book for couch potatoes. It contains no tales of derring-do ("Erik dropped out of the sky upon the unsuspecting Zero"), and it's so heavy it could do you injury if you dozed off. Rather, it presents the best collection of facts, figures, drawings, photos, and anecdotes about U.S. World War II fighters I've seen, and a whole lot more. For openers, Dean sketches American fighters of the 1920s and 1930s, along with the airplanes that might have fought in World War II but didn't make the grade, often because they were too goofy to be believed. He also talks about the elements that enable a fighter to fight, and includes a wonderfully lucid explanation of aircraft stability.

The main text is given over to the 11 airplanes that actually went to war, including the Brewster F2A Buffalo (509 delivered, mostly to desperate foreigners) and the humongous Northrop P-61 Black Widow (706 delivered, late in the war). Any kid with a flight simulator or a yen for model airplanes can name the rest: the shark-faced Curtiss P-40, the rotund Grumman F4F Wildcat and F6F Hellcat, the burly Republic P-47 Thunderbolt, the incomparable North American P-51 Mustang.... From 1939 to 1945, U.S. manufacturers built 100,090 combat-worthy fighters. "Today," Dean notes, "no one could pay for that number even if they were desired."

In the Schiffer tradition, photograph is piled upon drawing, table upon graph—74 for the Brewster Buffalo alone, which U.S. pilots flew in just one engagement, defending Midway on June 4, 1942. The drawings are generally taken from pilot's manuals and the like, giving the pages a pleasantly retro look.

Among such wonders, I was disappointed to find countless errors of spelling and punctuation, notably "Kittihawk" for the British Kittyhawk version of the big-jawed P-40. Never mind. Just as nobody will ever build so many fighters again, nobody is likely to attempt another such comprehensive (and doting) reference work, so we'll have to be content with this one.

—Daniel Ford writes about the Northrop Flying Wings in this issue.

Bold Endeavors: Lessons from Polar and Space Exploration *by Jack Stuster. Naval Institute Press, 1996. 377 pp., $32.95.*

We have become accustomed to viewing space exploration through the lenses of discovery and heroic accomplishment. Our presence in space—especially as we look to long stays on space stations, the moon, or Mars—may also be seen as social experiment. Different personalities and cultural values will be compressed in a near-unique and deeply stressful setting—the isolation and confinement of a mission in which crew members may be away from Earth for months or years. Norms of behavior and community may break down. The theme of sequestered individuals or a group going grimly haywire has a rich history in fact and fiction.

In *Bold Endeavors*, Jack Stuster invites us to consider the challenge of long-duration space travel from the perspective of his professional specialties, psychology and anthropology. The strains of life in space could be catastrophic. Salyut space station veteran Valery Ryumin once noted: "All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months." Stuster's focus, though, is not on the sensational but the pragmatic: The intensity and stress of an expedition may affect crew health, fitness, safety, and performance of duties and thus undermine the success of a mission undertaken at great public expense.

Stuster's aim is to offer guidelines to planners for understanding and managing the unique psychological, social, and

physical stresses of a space expedition. Stress in space travel, he suggests, is compounded by the small acts of living and working with others in a tight environment: Eating, sleeping, privacy, cleanliness, exercise, recreation, leadership style, work assignments, sex, religion, and expectations of behavior may all be sources of tension if not thoroughly evaluated in advance. Success in a space expedition will depend on designing routines of work and life that promote harmony and productivity.

While the book is aimed at policymakers and academics, the general reader may find it intriguing. Because the data on long-duration space travel is so slim, Stuster relies on an analogy: He uses the well-documented expeditions of the late 19th and early 20th century to the North and South Poles as a means of looking in detail at the problems of group life in isolation and confinement. Through diaries, ships' logs, and other accounts, Stuster engagingly analyzes the polar expeditions and their relevance for space travel. The curious result is that his prescriptions for space travel planners mirror the cultural values and planning ideas of a few of these earlier explorers.

As a "how to" analysis, Stuster's book may help planners design future missions. But his anthropological perspective reminds us that such planners will be charged with a weighty responsibility: creating a small society adapted to the unique conditions of space.

—Martin Collins is a space historian at the National Air and Space Museum.

Fairchild Aircraft 1926–1987 *by Kent A. Mitchell. Narkiewicz//Thompson, 1997. 184 pp., b&w and color photos, illustrations, $33.95 (paperback).*

Most airplane nuts know that Sherman Fairchild started out in aerial photography and then, needing a suitable platform, formed a company that built early high-wing cabin monoplanes, followed by Fairchild 24s, PT-19s, and C-119 Flying Boxcars. But how many know that Fairchild held more than 30 patents, was IBM's largest individual shareholder in the mid-1920s, or is credited with taking the first night-action synchronized-flash photo?

This well-organized work, while primarily a photo history, is packed with background information on Fairchild, the companies he founded, and the nearly 14,000 aircraft they built over 60 years. The description of each design is followed by a concise specifications box and detailed production statistics.

Though the book is a valuable addition to American aviation history, the quality of the line drawings is uneven. And I would have appreciated three-views of the C-119 and C-123 cargo holds to compare with the large three-views of the C-82's interior.

This is the third in a series of excellent books by the publisher and meets the standards set by the first two, which covered Vultee and Martin. It is clearly a labor of love by the author, who, as a boy in 1940, is pictured on the title page gazing up at a Fairchild 62A, the civilian trainer that led to over 8,000 PT-19s and other military and civilian variants.

—Sam Smith is a commercially licensed pilot and an amateur aviation historian.

Fighter Squadron at Guadalcanal *by Max Brand. Naval Institute Press, 1996. 232 pp., b&w photos. $25.95.*

Frederick Faust wrote westerns and romances under the name of Max Brand until he gave up fiction to become a war correspondent. Before leaving for combat, he interviewed the veterans of VMF 212, a Marine squadron recently returned from Guadalcanal. The result was this astonishing book, lost for half a century after its author was killed in Italy. Its

KID'S STUFF

I've Always Loved Airplanes *by Childbright Films (1267 Sweetwater Rd., Philadelphia, TN 37846), video, 1 hour 45 minutes. $19.95 plus $4.85 shipping and handling.*

I've Always Loved Airplanes gives a basic rundown of elements that make an airplane fly. The movie is aimed at kids around 8 to 10 years old.

It has ten sections, such as a museum of aviation, radio-controlled models, an airshow, and a tour of the biggest jet in America, the C-5 Galaxy. I personally liked the tour of the C-5 and the radio-controlled models. I did not understand why "Child's Fantasy Flight" was added. It shows a toddler on a teeter-totter acting as if he were flying.

There is only one other part where the movie came up short—a section called "Small Airplane Factory." It showed how a private airplane is built. However, it skipped a few steps—it went straight from welding pieces of the skeleton to showing how they put the wings on for the "Finishing Touch."

The movie was interesting and would make a good learning tool.

—Jared Schlenker, age 12, is a member of Pleasant Hill, Missouri's Boy Scout Troop 300. His goal is to be an Air Force or Navy pilot. I've Always Loved Airplanes *recently won a Bronze Telly Award.*

I Want to Be an Astronaut *by Maze Productions, 1997. 48 pp., color photos. $16.00 (hardcover).*

This book is good for young readers interested in space exploration. It has a lot of information about the education necessary to be an astronaut. Math and science courses will help you prepare.

I learned that astronauts train in giant water tanks to learn how to perform extravehicular activities in zero-gravity conditions. They also use KC-135 airplanes that fly parabolas and dive two miles to simulate weightlessness. You can have almost any job when you are an astronaut, like a doctor, scientist, photographer or pilot. If you are not sure whether you want to be an astronaut, there are space camps where you can see what it's like before you go to college.

The photographs are well-taken and interesting. I especially liked the photo of an F-16 pilot in a simulator. The photos taken during actual space missions really give you a good idea what it's like to be an astronaut flying miles above the earth. There are pictures of astronauts using cameras and equipment and life support systems that were quite complicated.

The book did have a few shortcomings. Some of the chapters seemed to be out of order; the book would tell about training, then what it's like to be an astronaut, then back to training.

I am more interested in space exploration than ever. *I Want to Be an Astronaut* encouraged me to put my skills to work. I encourage kids who are interested in becoming an astronaut to read it.

—Matt Roller is in the fourth grade at St. Peters School in St. Louis, Missouri. He first became interested in aviation and space after seeing the movie "Top Gun."

publication today is like turning on the radio and hearing Edward R. Murrow broadcasting live from Blitz-torn London.

The writing is easy and eloquent—the real malt whiskey, undiluted by second thoughts. The other guys are "Japs," when they aren't "sons of bitches," and our guys are outnumbered, exhausted, filthy, and unfailingly gallant. Their Grumman F4F Wildcats are no match for the Zeroes, but they usually come back with satisfying results. Heck, on one occasion they even sank two destroyers with machine gun fire. The myths were necessary in 1943 to maintain morale, but as published today, a more generous use of footnotes (there are a few) would have helped readers place the bravado in context.

The photos add hugely to the story. A pilot recalls his commander, drunk on adrenaline after landing at Henderson Field: "He hardly knew what he was doing, and he'd left his parachute on instead of leaving it in the plane." And here's the colonel himself—parachute pack dangling, knees bent, right hand strafing the left, photographed as he relives the battle for two grinning mechanics.

Writing *With General Chennault* under similar circumstances, journalist Robert Hotz made enduring heroes of the Flying Tigers of Burma and China. If this book had been published in 1943, the Marines of Fighting 212 might be as famous today as the Tigers. But that would have denied us the treat now available: reading it for the first time.

—Daniel Ford

BRIEFLY NOTED

Lockheed P2V Neptune: An Illustrated History *by Wayne Mutza. Schiffer, 1996. 286 pp., b&w and color photos, $49.95 (hardcover).*

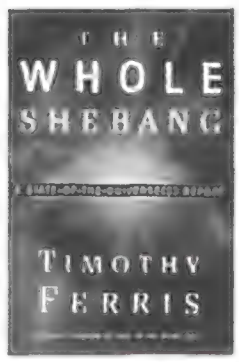
All you would ever want to know about the Neptune. Includes numerous and sometimes unusual military and civilian variants.

Vega Ventura: The Operational History of Lockheed's Lucky Star *by John C. Stanaway. Schiffer, 1996. 112 pp., b&w and color photos, illustrations, $19.95 (paperback).*

It's all here: serial numbers, squadrons, and plenty of photos of a little-recognized aircraft.

The Whole Shebang: A State of the Universe Report *by Timothy Ferris. Simon and Schuster, 1997. 393 pp., $25.00 (hardcover).*

In Woody Allen's film *Annie Hall*, a flashback shows Woody as a schoolboy



who's just learned that the universe is expanding. He reasons that "someday it will break apart and that will be the end of everything." So he refuses to do his homework. "What's the point?" he asks his bemused mother.

Anyone else concerned about the fate of the universe will find *The Whole Shebang* enlightening, if not necessarily reassuring for the long run.

The expansion of the universe is one of the most revolutionary discoveries in all of science. It was predicted by Einstein's general theory of relativity, but Einstein, who believed that the universe was static (as did most scientists of the day), assumed his equations were in error. To eliminate the expansion, he added a "cosmological constant," a move he later admitted was his greatest blunder. By 1929, Edwin Hubble had shown that the universe was, in fact, expanding. This was the dawn of modern scientific cosmology.

The Big Bang theory is now widely accepted as the mechanism by which this expansion originated. *The Whole Shebang* outlines the basic tenets of the standard Big Bang theory, and the modifications made to it as scientific knowledge grew. In the process, the book delves into such mysteries as the problem of dark matter, how stars and galaxies evolved, cosmological inflation, and quantum weirdness.

Although this is not "Cosmology for Dummies," general readers will not find *The Whole Shebang* incomprehensible. Despite the apparently daunting nature of his task, Ferris has produced a cogent and literary book that is informative without being overwhelming.

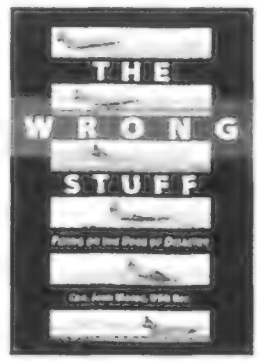
Throughout, Ferris leavens explanations with engaging portraits of those who made crucial discoveries. Often these are fascinating but little-known figures, such as Alexander Friedmann, who was the first to propose a mathematical model of an expanding universe, despite living a pauper's life in the Soviet Union. Or Vera Rubin, who was denied admission to Princeton's doctoral program in the early 1950s because she was a woman. Undaunted, she decided she "was just going to go off and do a problem that nobody would care about while I was doing it." In doing so, she essentially discovered dark matter, which may make up as much as 90 percent of the mass of the universe and is now one of cosmology's most important areas of inquiry.

One of the only shortcomings of this book is its lack of illustrations. Although it frequently refers to images from the Hubble Space Telescope, the book contains none, nor any other pictures of the spectacular phenomena it describes. A few such images would have heightened the text's brilliant depictions of the universe.

—James Hyder was a lecturer in the National Air and Space Museum's Einstein Planetarium for 12 years.

The Wrong Stuff *by John Moore, Commander, U.S. Navy (ret.) Specialty Press, 1997. 214 pp., b&w photos, $19.95 (hardcover).*

John Moore can say without hesitation that he has made more crash landings than any other pilot. Still, the title of his biography is a bit misleading: Moore is no Wrong-Way Corrigan of the jet-jock set. A naval aviator and then a test pilot in the transitional era between World War II and Vietnam, Moore had a cockpit's-eye view of "the Korean thing," as he calls it, as well as some of the more bizarre and dangerous experiments that the government foisted upon the test pilots too junior or too brave to say no.



There was the Vought F7U Cutlass, by every account a lemon that Moore and his ilk were ordered to make work despite its hideous and unforgiving characteristics. And there was the inflatable rubber Flexdeck program, begun when some bureaucratic genius realized a fighter would fly much faster without all that heavy and complicated landing gear and finished after some highly skilled pilots inflicted critical injuries upon themselves. Moore somehow managed to survive a record-breaking number of such landings and a few other dire scrapes to write this engaging account. There's a lot of real-man stuff here, facing commies and death with self-deprecating grin and all that. But that's what you expect. The book has a conversational tone, giving you the feeling that you're hanging out in a warm den on a snowy evening, fire crackling, while Moore spins his tales.

—Phil Scott is the editor of Canvas, Steel and Wire: A Documentary History of Early Flight, *to be published this fall by Princeton University Press.*

CALENDAR

June 1–23
The works of naval aviation artist R.G. Smith are featured in a one-man retrospective. Phippen Museum, Prescott, AZ, (520) 778-1385.

June 1–July 13
"First in Space: The Star City Cosmonauts Collection." An exhibit of Russian space artifacts. City Hall, Nassau Bay, TX, (409) 762-3930.

June 6–8
Mid Atlantic Air Museum World War II Commemorative Weekend. Reading Regional Airport, PA, (610) 372-7333.

June 7 & 8
Asheboro Airshow. Asheboro Municipal Airport, NC, (910) 629-4161.

June 13–15
Wings Over Batavia Airshow. Genesee County Airport, Batavia, NY, (716) 243-0690.

June 14
EAA Chapter 7 Fly-In. Aeroflex-Andover Airport, NJ, (201) 786-5682.

Wings and Wheels Fly-In and Auto Show. Pottstown-Limerick Airport, PA, (610) 277-7022.

June 14 & 15
Father's Day Airshow. Camarillo Airport, CA, (805) 985-4058.

June 22
Hoosier Warbirds Fly-In. Auburn Airport, IN, (219) 925-6285.

June 28
Mogollon Airpark Fly-In/BBQ. Overgaard, AZ, (602) 661-7586.

July 4
Rockport-Fulton Airshow. Rockport, TX, (800) 242-0071.

July 12
Grass Valley AirFest. Nevada County Airpark, Grass Valley, CA, (916) 274-1040.

July 19
Lion's Club "Fly-In-Whitefish Boil." Washington Island, WI, (414) 847-2770.

July 25–27
New Jersey Festival of Ballooning. Solberg Airport, Readington, NJ, (201) 884-8700.

Norseman Float Plane Festival. Red Lake, Ontario, Canada, (807) 727-2809.

CREDITS

Choices. Paul N. Uhlig is a cardiothoracic surgeon in Wichita, Kansas.

Hyperventilation. Dan Kovalchik is the computer systems administrator at the Delta launch complex at Cape Canaveral Air Station in Florida. He and the other blockhouse personnel have newfound respect for safety engineers after a Delta rocket exploded last January at an altitude of only 1,500 feet.

The End. Joseph Bourque is a freelance writer and private pilot based in Bozeman, Montana. His motto is "Better to wear out than rust out."

Photographer Robb Kendrick spends much of his time traveling on assignment for *National Geographic*.

Some Assembly Required. A veteran writer specializing in the space program, Henry S.F. Cooper Jr. is the author of eight books.

A resident of Highland Heights, Ohio, Paul DiMare has been a professional illustrator for 20 years.

Tullo and the Giant. Robert A. Hanson is a retired Air Force lieutenant colonel who flew 122 combat missions in Vietnam in the F-4E; he was awarded both the Silver and Bronze Stars.

Hard Landings. Andrew Chaikin's new book, *Air and Space: The National Air and Space Museum Story of Flight*, is due out this fall from Bulfinch Press.

Illustrator Jan Adkins is a former art director for *National Geographic*. He has written over 30 books.

Wright v. Curtiss (Cont'd.) New York City writer Phil Scott studied the Wright brothers and Glenn Curtiss extensively while researching his book *The Shoulders of Giants: A History of Human Flight to 1919* (Addison Wesley, 1995).

Digital artist David Peters is a frequent contributor to *Air & Space*.

The Edwards Diaries. Contributing editor Daniel Ford is editing Glen Edwards' diaries for publication by Smithsonian Institution Press. He is grateful to Patricia Edwards for permission to use material from her manuscript *Touched With Fire*, a biography of Glen Edwards.

Roy Wolford worked at Northrop for 58 years—27 as chief photographer.

Proud to Be American. Lester A. Reingold is a frequent contributor to *Air & Space*.

ON THE WEB SITE

The Northrop Wing

The protruding tail cone of the YB-49, which was originally designed to be a stinger with four .50-caliber machine guns, made the Flying Wing nearly 54 feet long. Its wingspan was the more impressive dimension: 172 feet—31 feet greater than the Boeing B-29 strategic bomber it was intended to replace. Find out more intriguing facts about the Flying Wing by visiting *Air & Space/Smithsonian*'s Web site. (www.airspacemag.com/supp/JJ97/Wing.html).

MORE UGLIES

One thing the *Air & Space* staff learned, after several near-fistfights over our "Plug-Ugly" feature, is that ugliness, too, is in the eye of the beholder. It is therefore with complete subjectivity and without apology that we offer you more of what *some* people called "aircraft too ugly to print in a magazine." Visit at your own risk. (www.airspacemag.com/supp/JJ97/uglies.html).

FORECAST

In the Wings...

Inventing the Spy Plane
How reconnaissance hit new heights with the U-2 and SR-71.

The Reconstructionists
Putting a smashed airliner back together may reveal the cause of a crash.

Who's Your Tailor?
A whole slew of engineers and seamstresses, if you wear a spacesuit to work.

Logging Hours
Pilots wanted: Low pay, long hours, but, at the end of the summer, a big step toward an Airline Transport rating.

Happy Anniversary, Bell X-1
A scrapbook of X-1 snapshots and an accompanying X-marks-the-spot map of historic sites at California's Edwards Air Force Base.

JOHN HEINLY

Proud to Be American

It all began 27 years ago with a leather flightsuit that was heading for the trash. When Paul Kent learned that a friend of his, a retired American Airlines captain, was about to discard one, Kent rescued the relic. Kent himself was also retiring, having worked for 45 years as a mechanic, mostly with American, and his find inspired him to embark on a mission to acquire and preserve the airline's memorabilia. Kent's collection eventually grew to more than 10,000 items, and in the early 1990s it became the nucleus for a new museum devoted to American and the airline industry in general.

Located four miles south of Dallas-Ft. Worth International Airport, the museum is named after C.R. Smith, the man who served as American's president from 1934 to 1968. No detail was too large or too small for Smith's attention, and the museum reflects his pervasive influence. One exhibit is devoted to the man himself, featuring his desk and a video about his life, but his presence is felt elsewhere as well, through quotations and numerous examples of his accomplishments.

It was Smith who in 1935 urged Donald Douglas to enlarge Douglas Aircraft's DC-2 so that it could accommodate sleeping berths; the request ultimately led to the design of the DC-3. Outside the museum stands an example of that landmark airliner—the *Flagship Knoxville*, which flew for the airline from 1940 to 1948. It's one of only a handful of DC-3s built to American Airlines specifications that survive today.

When the *Knoxville* was located in 1991, it was nearly a derelict; most recently, it had been used to spray mosquitos in South Carolina. Some 12,000 volunteer hours at American's Tulsa maintenance base were needed to return it to its former glory. "Then," recalls Otto Becker, retired American senior vice president and one of the project leaders, "we flew it to DFW with a full load of passengers." Becker adds that the crew on the flight was made up of American veterans: an 80-year-old pilot, a 75-year-old copilot, and a 79-year-old stewardess (wearing her original uniform).

In the years since the *Knoxville* arrived at the museum, it has once again started to deteriorate. The paint is peeling, and there are holes in the fabric-covered rudder, ailerons, and elevators. An effort is under way to build an enclosure for the DC-3. The planned structure, reminiscent of a 1930s hangar but with enough glass so the *Knoxville* will be visible from the highway nearby, will also give the museum more exhibit space.

Inside, visitors are first treated to a large-screen film celebrating flight and American Airlines. (The next one scheduled to run, *The Spirit of American*, is narrated by Charlton Heston and accompanied by the music of Michael Bolton.) The theater's entranceway looks like a jet bridge, and the audience sits in first-class airliner seats. The staff report that viewers often dutifully fasten their seat belts.

After the movie, visitors can wander among the historical exhibits. Artifacts displayed include a pilot duty log from Robertson Aircraft Corp., an American predecessor, handwritten by its chief pilot, Charles Lindbergh. From the days of the Ford Tri-Motor, there's an "air sickness cup": A far cry from the discreet folded paper bag we still see today, this is a large cardboard canister, designed for the seriously nauseated. A card handed to passengers during World War II explains that for security reasons the stewardess had to keep the shades drawn over windows during takeoff and landing and when flying over restricted areas—"and you're not supposed to peek, or she'll have to report you." And there's a reminder of the indignities flight attendants have sometimes suffered at the hands of airline marketing: a Daniel Boone-style coonskin hat, part of the uniform that went with "Americana" service introduced in 1969.

The museum uses some clever techniques to teach visitors about airline operations. On a full-scale baggage claim conveyor belt, one of the suitcases lies opened, and amid the clothes is a video monitor explaining baggage-handling procedures. Another monitor, this one peeking out from a cargo container, shows a video on cargo operations.

Hands-on learning is stressed throughout. Sit in a Boeing 757 cockpit mockup and press each instrument for a video explanation of its function. Examine a detailed airport model and press buttons to hear about what goes on in such areas as passenger ticketing, security, and crew operations. Sit at a terminal and get a demonstration of computer-based training for flight attendants and pilots. At another terminal, see the SABRE computer-reservation system in action. Hardware on display includes a General Electric CF6 turbofan engine from a McDonnell Douglas MD-11, the cabin of a Boeing 767, the main landing gear of a 727, and the nose section of American's newest airliner, the Fokker 100.

The museum's centerpiece is a group of eight life-size figures representing such jobs as flight attendant, pilot, gate agent, and cargo handler. Interactive videos nearby show actual employees describing their work.

The "Flightlab" section features hands-on exhibits that teach various principles of flight, such as three-axis control, lift and drag, and the anatomy of airplanes. At one area in this section, visitors can use paper and crayons to make rubbings of brass plaques depicting such aircraft as the DC-3 and the Boeing 707. Such activities are set up with children in mind, says collections curator Shannon Risk, "but I've seen adults making rubbings with no children in sight."

—Lester A. Reingold

American Airlines C.R. Smith Museum, 4601 Highway 360 at FAA Road, Fort Worth, TX 76155. Phone (817) 967-1560. Open Tues., 10 a.m.–7 p.m.; Wed.–Sat., 10 a.m.–6 p.m.; Sun., noon-5 p.m.; closed Mon. Admission free.

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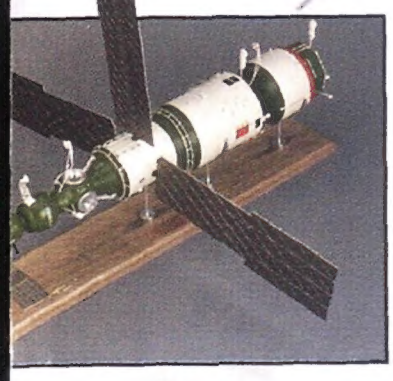

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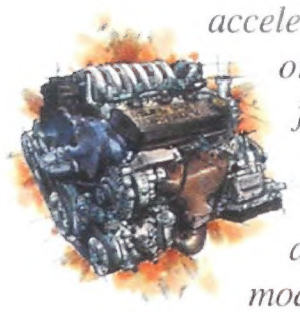

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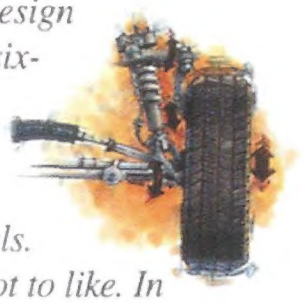

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